THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

VOL. 43 APRIL 1950 PART 1

CONTENTS

	PAGE
A REFERENCE TELEPHONE SYSTEM FOR ARTICULATION TESTS—J. Swaffield and R. H. de Wardt	1
IMPROVED METHOD OF CABLE BUOY RECOVERY	8
A SURVEY OF MODERN RADIO VALVES—Part 4—Transmitting Valves for use up to 30 Mc/s.—K. D. Bomford, M.Sc., A.M.I.E.E., and A. H. F. Hunt	10
THE RECOVERY OF TWO TIMBER LATTICE MASTS—Capt. S. Helm. A.M.I.E.E.	16
AN ELECTRONIC DISTORTION MEASURING SET FOR START-STOP TELEGRAPH SIGNALS—L. K. Wheeler, B.Sc.(Eng.), A.M.I.E.E., and R. S. Tissington, B.Sc.(Eng.), A.M.I.E.E.	18
TELEVISION RADIO-RELAY LINKS—A. H. Mumford, O.B.E., B.Sc.(Eng.), M.I.E.E., and Capt. C. F. Booth, O.B.E., M.I.E.E. ..	23
TESTING FACILITIES IN H.M.T.S. MONARCH—P. R. Bray, M.Sc.(Eng.), A.M.I.E.E.	36
A METHOD OF REDUCING THE VIBRATION FROM DIESEL ENGINE GENERATING SETS—J. H. Alderson, M.A., A.M.I.E.E.	43
NOTES AND COMMENTS	50
INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS ..	50
REGIONAL NOTES	51
JUNIOR SECTION NOTES	54
STAFF CHANGES	57
BOOK REVIEWS 7, 17, 22, 35, 48	

Price 1/6 net

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

STUDY AT HOME

You Can Have a College Training For a Few Shillings Monthly

IN YOUR SPARE TIME

CITY and GUILDS
(Telecommunication)
EXAMINATIONS

The most progressive and most successful Correspondence College in the world

To every student we send a written Guarantee of Tuition until the examination is actually passed

Our tuition is so graded that each stage is reached without difficulty.

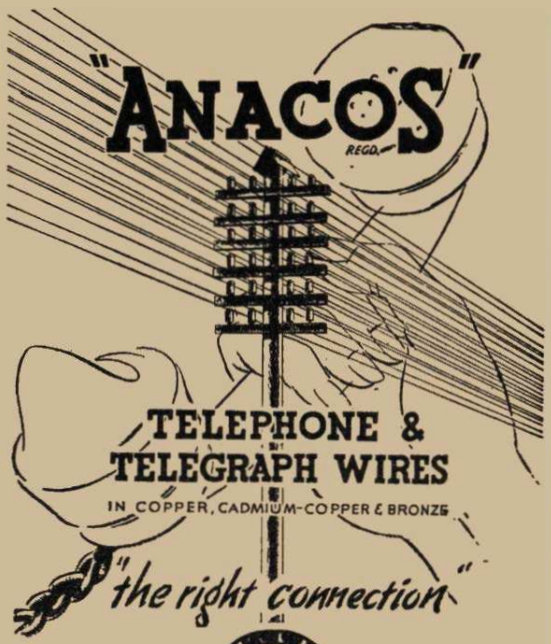
Personal attention is given to every student.

FULL PARTICULARS AND ADVICE SUPPLIED FREE.
WE TEACH BY POST IN ALL PARTS OF THE WORLD.

The Bennett College Limited

Dept. 24, THE BENNETT COLLEGE, SHEFFIELD

"ANACOS" REGD.



TELEPHONE & TELEGRAPH WIRES
IN COPPER, CADMIUM-COPPER & BRONZE

"the right connection"

FS

FREDERICK SMITH & COMPANY
(Incorporated in The London Electric Wire Company and Smiths, Limited)
ANACONDA WORKS, SALFORD 3, LANCS.
Phone: Blackfriars 8701 (9 lines) • Grams: "Anaconda," Manchester

•PROCESS TIMERS

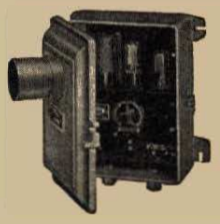
Spelling and Sequence Timers, etc. Cycling and Hand or Auto Re-setting. Periods 1/10th second to a week.

Ask for leaflet PT/PO

•PHOTO-ELECTRIC APPARATUS

COUNTS
CONTROLS
PROTECTS

Ask for leaflet 108/PO



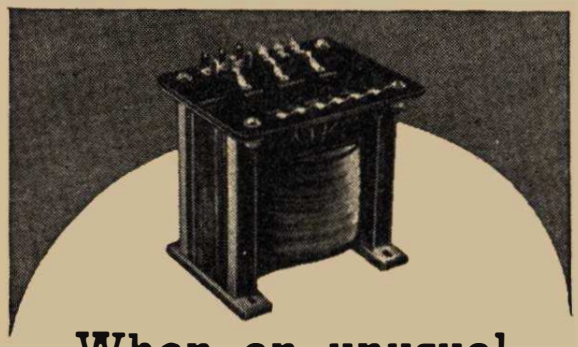
•RELAYS

Mercury-Switch, Miniature, Latching, Stepping, Differential, Sensitive and other types.

LONDEX LTD.

Manufacturers of Remote Control Apparatus

207 ANERLEY ROAD, LONDON, S.E.20 *Tel.: SYDenham 6258*



When an unusual Specification is required.

We can give you the benefit of 20 years' experience in transformer construction and design. We manufacture quantities but we do NOT mass produce. Every Instrument is built to suit your most exacting individual specification.

Send your enquiries for the personal attention of our Mr. W. Bryan Savage.

SAVAGE TRANSFORMERS LIMITED DEVIZES

SAVAGE TRANSFORMERS LTD. • NURSTED ROAD, DEVIZES, WILTS.

THE POST OFFICE
ELECTRICAL ENGINEERS' JOURNAL

Vol. 43 April, 1950 Part 1

A Reference Telephone System for Articulation Tests

J. SWAFFIELD, and
R. H. de WARDT

U.D.C. 621.395 : 534.78

The C.C.I.F. is studying the possibility of using ratings based on articulation measurements, as distinct from the volume ratings (reference equivalents) at present in use, for specifying the standard for international telephone transmission. The British Post Office has recently supplied a high quality reference telephone transmission system for use in developing and maintaining such a standard. The reference system and associated apparatus (known collectively as the ARAEN) are now installed and in use at the C.C.I.F. Laboratory in Geneva.

Introduction.

THE Fourth Commission d'Etudes of the C.C.I.F. is responsible, among other things, for specifying the quality of transmission for international telephone circuits with particular reference to the local network (i.e., speaking and listening conditions, subscribers' sets and local lines) aspects of the problems ; it is also responsible for the work of the C.C.I.F. (formerly SFERT) Laboratory. The work of the 4th C.E. in January to June 1949 has already been reported[1] and it will suffice to say here that following the move of the SFERT Laboratory from Paris to Maison des Congrès, Geneva, late in 1948, it was decided :—

(i) That the SFERT would be set up in the new laboratory and would be used solely for the measurement of Reference Equivalents (i.e., ratings by volume balancing).

(ii) That a new equipment should be obtained to serve as a reference standard for ratings based on articulation measurements.

(iii) That, in view of the fact that the SFERT would form only a part of the equipment, the name of the laboratory should be changed to the " C.C.I.F. Laboratory."

The SFERT[2] (*Système Fundamental Européen de Référence Téléphonique*), presented to the Laboratory in 1928 by the American Telephone and Telegraph Co., is a high-quality, stable reference system and has served the purpose of a reference standard for volume measurements satisfactorily for over 20 years. However, the move and the general re-equipment of the Laboratory, together with the increasing difficulty of maintaining the SFERT (much of which is obsolescent) and the decision of the 4th C.E. to pursue the question of rating by articulation, indicated that a good opportunity had arisen for providing a new reference standard.

Ratings based on articulation measurements known as A.E.N. (*Affaiblissement Equivalent pour la Netteté*) ratings have been specified in principle but the method and various details of the technique require further study (which is in progress) before there can be any question of such ratings superseding Reference Equivalents.

A high-quality transmission reference system of modern design was offered to the Laboratory by the British Administration on loan for an indefinite period for use in further studies of the A.E.N. technique. The offer was accepted and the equipment, which is now installed and in operation in the C.C.I.F. Laboratory, has been named ARAEN (*Appareil de Référence pour la détermination des Affaiblissements Equivalents pour la Netteté*). In addition to the reference system proper (i.e., the transmission part of the apparatus) the complete ARAEN, as installed, includes much auxiliary equipment essential for A.E.N. measurements. The installation at Geneva was carried out in May and June 1949, and two sets of similar equipment are now in use at the Post Office Research Station, Dollis Hill.

The purpose of the present article is to describe the ARAEN itself ; it is hoped to publish an account of the development of A.E.N. as a method of rating of transmission equipment as soon as sufficient information has been obtained to permit an exact specification of the technique.

Design Principles of the Reference System

General.

The present techniques of articulation testing (and subjective transmission testing generally) are essentially comparative ; they provide a result which expresses only the difference between the transmission characteristics of two or more systems. Thus the technique is obviously more useful if the comparisons are always made against one particular system, which is usually known as a " Reference System." From this aspect the main criterion of choice of a Reference System is stability of transmission characteristics. This leaves a wide choice of possible characteristics, but for various reasons the system will be most useful if it has the best possible transmission characteristics. A free air path remote from all

[1] For references see end of article.

reflections is envisaged as the ideal reference system from these points of view, i.e., stability and transmission quality. There is, however, a practical requirement which must also be satisfied if the system is to be used for articulation testing. The attenuation between the talker and listener must be variable, and it must be possible to increase the attenuation until the received speech signal is nearly inaudible. With an air-path system this could, in theory, be attempted by increasing the distance between the talker and the listener, but the difficulties of obtaining non-reverberant and non-reflecting conditions for the distances required are insurmountable, as are various other difficulties.

The use of variable acoustic noise as a means of simulating attenuation has also to be ruled out for practical difficulties and because it is not possible in this way to simulate non-reactive attenuation over a wide range of attenuations since the natural ear threshold will tend to be effective for low noise and the noise spectrum will provide the threshold for high noise conditions.

The concept of the air path is, however, basically attractive and the system developed by the Post Office has retained the concept, but realised it in a more practical form. The major part of the air path is replaced by an electro-acoustic system having exactly the same characteristics as that part of the air path which it replaces. To obtain a quantitative relationship the whole system is related to an air path of specific dimensions; the transmission characteristics between talker and listener afforded by the system, when used with a specified talking distance and overall gain, are equivalent to those existing when a talker speaks to a listener over a one-metre air path (an air path existing under reflectionless and non-reverberant conditions). This ideal condition is qualified by the fact that the Reference System uses monaural listening; it is therefore convenient to envisage monaural listening for the air path. The use of a system with monaural listening simplifies the equipment, and may perhaps be justified by the fact that it will be used to rate telephones which are themselves invariably monaural.

Electric and Acoustic Requirements.

The Reference System consists essentially of a microphone connected by a system of amplifiers and passive networks to a set of receivers. The overall performance of the equipment is specified by the requirement that the system must produce in the listener's ear a sound pressure which is an exact replica of that which would occur if the listener used the air path. This actually means that the system should not have a flat frequency response, because the obstructing effect of the human head alters the sound pressure in the entrance of the ear when an actual air path is used. Apart from this effect which must be reproduced in the system, the frequency response should be flat over the range of frequencies required for speech, say 80 to 6,000 c/s. The system should also be free from non-linear distortion, but this requirement presents little difficulty and it has not been found necessary to call for any precise specification of linearity.

To ensure that the system is stable and free from variation, the components and design must be carefully studied to ensure that it has the utmost reliability. The use of the reference system, though supervised by technical staff, is largely in the hands of non-technical operators; hence it should be as robust as possible and the controls should be the simplest that can be devised. For the electro-acoustic components the requirements of stability and robustness are probably best met by moving-coil receivers and microphones. With microphones and receivers high quality can only be obtained by some sacrifice of sensitivity; therefore the system needs several amplifiers whose gain stability can best be adequately ensured by sufficient negative feedback. All the components used in the system should be chosen carefully from the aspect of stability, special attention being paid to switch and relay contacts (particularly those in the main transmission path). Adequate facilities should be provided for testing all parts of the equipment, and some method of dividing the main transmission path is necessary both for testing and for fault location.

Construction.

The system should be constructed so that it is easily accessible both for general use and for maintenance. In this case the requirements are best satisfied by building the equipment on standard 19-in. panels mounted on apparatus racks, with the panel covers projecting through the racks (back-mounting covers). The layout of the components on the panels should be planned to provide the maximum accessibility; this applies particularly to all controls.

The Reference System

A high-quality speech-transmission system, satisfying the requirements outlined above, has been designed in the Post Office Research Branch.

Fig. 1 shows the schematic arrangement of the Reference System consisting of three groups of equipment, the sending end comprising a microphone and amplifier system, the junction which consists of an attenuator and switching system (together with a filter, primarily for use with commercial systems under test) and finally the receiving end which consists of a further amplifier, equalisers and receivers.

The Sending End.

The design of this part of the system is dependent on two factors, the overall frequency response, and the level required at the output. The design objectives were a flat frequency response and a level of 1V when the microphone was talked into under specified conditions. The microphone (S.T.C. 4021E) used with the system does not have a perfectly flat frequency response, but all microphones exhibit the same characteristic, a gradual rise to a 5 db. peak at 500 c/s. When used with standard speaking conditions* and a speaking distance of one foot, the microphone output is approximately —85 db. relative to 1V. There is some variation in this figure and therefore it is

*A convenient speaking level standardised for articulation tests and specified acoustically.

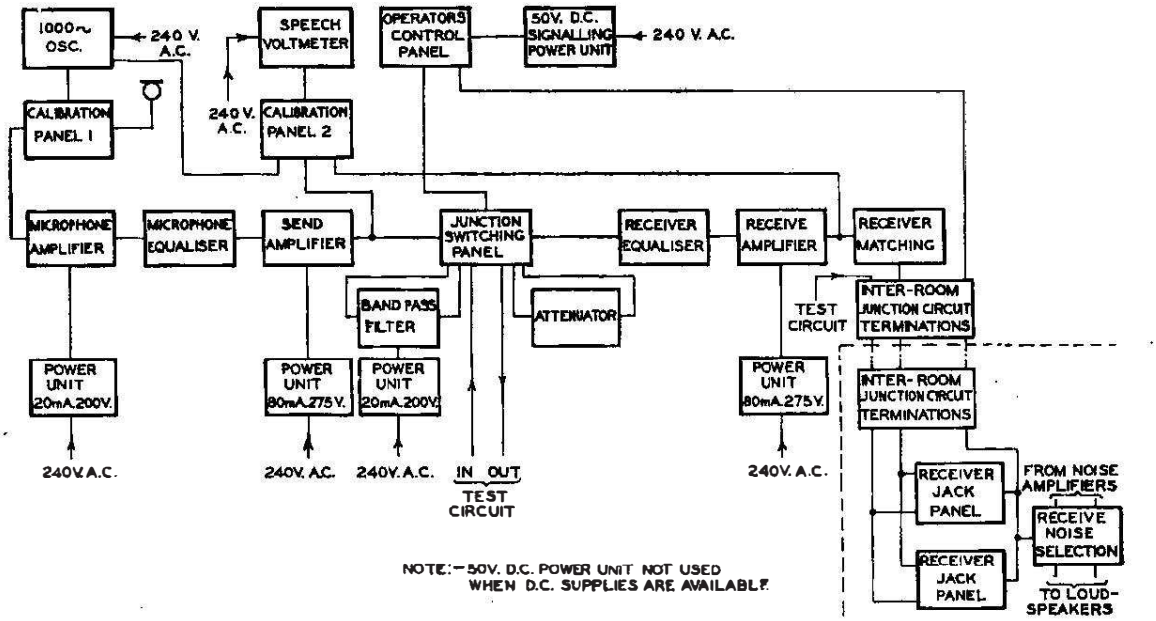


FIG. 1.—ARAEN; BLOCK SCHEMATIC DIAGRAM OF TRANSMISSION PATH.

necessary to provide a variable gain control at some point in the sending end.

The sending end consists of four main components; the microphone connected to the microphone amplifier, which is followed by the microphone equaliser and another amplifier known as the send amplifier. This arrangement was adopted to allow the equaliser to be placed at a point in the circuit where the level was not so low as to cause trouble from induced noise, or so high as to make the design of inductors uneconomical.

The microphone amplifier has two stages and operates at a fixed gain maintained constant by using 20 db. of negative feedback. Both current and voltage feedback are used, the proportions being arranged to make the output impedance 600 ohms. The design is straightforward except where special precautions have been taken to reduce the noise level at the output; these include the use of a special low-noise triode in the first stage, and special earthing precautions particularly on the input circuit. The gain of the amplifier is 47 db. and circuit noise level at the output is better than 85 db. below 1V.

The equaliser which follows the microphone amplifier is a constant impedance network having an insertion loss which is the inverse of the frequency response of an average microphone.

The send amplifier follows the equaliser and feeds directly into the junction; it has three stages, the final one being capable of handling 1·5W. The gain of this amplifier is also stabilised by both voltage and current feedback, proportioned to give an output impedance of 600 ohms. The gain can be varied by two controls; a calibrated potentiometer moving in 2 db. steps, which is placed between the input transformer and the grid of the first stage, and ganged variable resistances in the feedback paths moving in 0·2 db. steps. The amplifier is normally used with a gain of 42 db., but this can be varied over a range of 20 to 64 db. in 0·2 db. steps by the two controls mentioned previously.

In articulation testing the talker is required to speak at a fixed level and thus some instrument must be provided to indicate the talking level. The characteristics of such instruments are specified by the C.C.I.F.,[3] and the instrument (known as a speech voltmeter) used with this system complies with the specification except in respect of one of the ballistic properties of the indicating instrument. The speech voltmeter is connected across the output of the send amplifier which is the point where a level of 1V should exist when the talker is speaking. A 1,000 c/s oscillator is provided with the speech voltmeter for calibration purposes; this oscillator also has a low-level output (80 db. below 1V) which can be connected in place of the microphone for checking the overall gain of the system. The speech voltmeter can be used as a level-measuring set for these measurements. The various oscillator and speech voltmeter connections are made by rotary switches.

The overall gain of the sending end depends on the sensitivity of the microphone. A mean figure is calculated for each microphone and the gain of the send amplifier is adjusted accordingly. Between microphones the variation of mean sensitivity is of the order of 1 db.

The Junction.

The term junction covers the variable non-reactive attenuator and any filters or other equipment connected between the sending and receiving ends. In the Post Office system these are connected to a switching panel which allows the attenuator to be used by both the Reference System and by commercial systems which are being tested. A 300-3,400 c/s band-pass filter is provided with the equipment and

can be included in the junction if required. The attenuator (and filter) are changed from one circuit to another by relays mounted on a switching panel controlled by a key and selector switches placed near the operator at the talking position. The switching panel has U-link break points for inserting special equipment, and the switching arrangements have been designed so that the combination of components (i.e., attenuator, filter, etc.) can be changed when the junction is switched from one circuit to another. The switching is designed to enable two commercial circuits to be compared with the Reference System.

The attenuator panel contains two high-grade H-type 600 ohms variable attenuators, controlled by rotary switches. One attenuator covers the range 0-10 db. in 1 db. steps; the other 0-100 db. in 10 db. steps.

The band-pass filter included in the equipment has been specially designed to have an insertion loss/frequency characteristic of a typical carrier system. (The band 300-3,400 is in accordance with C.C.I.F. recommendations.)[4] The filter consists of separate low- and high-pass sections with an amplifier between them. The gain of the amplifier is adjusted so that the overall insertion loss in the pass band is zero.

Receiving End.

The most important components are the high-quality moving-coil receivers (S.T.C. 4026A). The frequency response of these is not quite flat, consequently some equalisation is necessary. The overall response of the system also includes the obstruction effect of the human head and it is necessary to introduce a weighting network into the receiving end to allow for this. In practice it was found easier to design one network which both compensated for the response of the receivers and introduced the obstruction effect.

To enable four listeners to listen simultaneously, four receivers are connected in series. This method of connection was chosen as the probability of a receiver circuit fault affecting all listeners is much greater. (The usual receiver circuit faults are high-resistance cords or plugs.) To compensate for the loss of the equaliser network it is necessary to introduce some gain into the receiving end. The requirements call for an amplifier with less gain than the send amplifier but capable of handling the same maximum output level. To avoid duplicating designs, a send amplifier with a different ratio input transformer is used, giving a normal gain which is 20 db. lower.

The receiving end is arranged so that the output of the junction feeds into the receiver equaliser, then through the receive amplifier to a matching transformer and then to the receivers (total impedance of four receivers, 88 ohms resistive). The listeners sit in a sound-proof room remote from the sending end and their equipment is connected to the main equipment by a system of junction cables. The output of the matching transformer is fed to jack-panels at the listening positions, where the receivers are plugged in. All four receivers must obviously be in circuit when the system is in use, irrespective of the number of listeners.

EQUIPMENT ASSOCIATED WITH THE REFERENCE SYSTEM

Noise Generation and Measuring Equipment.

This equipment provides room noise at the operators' listening position, produced by loudspeakers suspended from the ceiling of the sound-proof room, and facilities for measurement of the level of this noise.

Fig. 2 shows, in block schematic form, the noise generation equipment which consists of a continuous spectrum noise generator, weighting networks to give the noise the required spectrum and power amplifiers which feed the loudspeakers. The continuous spectrum noise is obtained by amplifying the fluctuation noise produced by a gas-filled triode. This source is eminently suitable as it produces a comparatively high level of noise with a flat spectrum (i.e., the energy per c/s is constant). The noise is then fed through a weighting network to give it the spectrum described by Hoth[5] as that of the average room noise occurring in subscribers' premises. To compensate for the loss introduced the weighting network is followed by another amplifier.

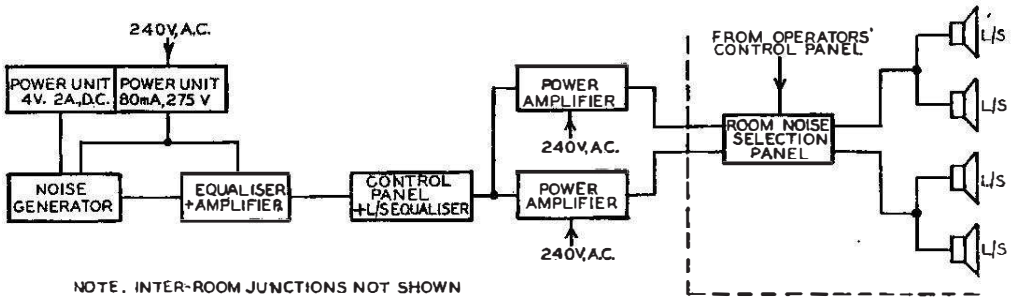


FIG. 2.—ARAEN; BLOCK SCHEMATIC DIAGRAM OF NOISE GENERATION EQUIPMENT.

The output of the weighting network amplifier is fed through an equaliser, which compensates for the characteristics of the loudspeakers and listening room, then through variable attenuators to the power amplifiers which supply the loudspeakers. The system is thus designed so that the overall frequency response of the equaliser, power amplifiers, and loudspeakers is flat.

To measure the noise level produced by the loudspeakers in the listening room, a sound-level meter is provided on the racks adjacent to the room-noise level controls. This meter consists of a high-quality moving-coil microphone (S.T.C. 4021E) in the listening room, and a microphone amplifier, weighting net-

work and speech voltmeter on the rack. The complete chain of components complies with the American Standard for sound-level meters.[6] A calibrating oscillator and switching arrangements are included with the system to provide facilities for checking the gain of the microphone amplifier and the sensitivity of the speech voltmeter. The switching arrangements also allow the circuit between the microphone and the microphone amplifier to be run over a cable normally used for an intercommunication circuit.

Intercommunication Equipment.

When carrying out articulation tests, the operator at the talking position has to pass instructions to the others at the listening position and they have to indicate when they are ready to start. A simple loudspeaking telephone system is installed with the Reference System to provide these facilities. Facilities are provided for holding a conversation between the talking and listening positions, and between the noise-generation equipment racks and the listening position (this facility is useful when adjusting the noise level).

The equipment provided at each position consists of a 3½-in. loudspeaker mounted on a panel together with a change-over key and a volume control. With the key in the normal position the loudspeaker is connected to the output of a three-stage amplifier mounted on the noise equipment racks. When the key is operated the loudspeaker is used as a microphone and is connected to the input of the amplifier feeding the loudspeaker at the listening position. The loudspeaker on the noise equipment racks, though having its own amplifier, is effectively in parallel with that at the talking position. Switching is provided to cut it in and out as required.

Transmission Measuring Equipment.

The performance of the electrical elements of the system can best be checked by pure-tone transmission measurements. To facilitate these a wheeled rack containing suitable measuring equipment is provided with the system. The equipment consists of a variable-frequency RC oscillator (30 to 30,000 c/s), a level-measuring set and a switching panel which enables a variety of measurements to be made.

The oscillator is essentially a wide-band three-stage amplifier with overall positive and negative feedback paths taken from the cathode of the third stage. The positive path contains the frequency-selective network, which is of the series-parallel resistance-capacitance type. In order to obtain low harmonic content and constancy of output level at different frequencies, amplitude limitation is effected by a number of tungsten filament lamps in circuit with the frequency-selecting network.

The controls of the selective network move in discrete steps and are arranged in decades to cover the range 30 to 3,000 c/s in 1 c/s steps and 3,000 c/s to 30,000 c/s in 10 c/s steps. A continuously variable control, which sweeps over the smallest steps of the decade is also provided. The oscillator is fitted with a temperature-controlled oven for the frequency-selective networks and when this is in use the frequency of oscillation is stable to within 0·04 per cent. (The oven takes roughly 15 minutes to reach its stable temperature.) A variable non-reactive attenuator is provided in the output giving 1 db. steps over a range of 60 db.

The level-measuring set used with this equipment is the standard Tester RP790. The third panel, which contains the switching arrangements, provides facilities for quickly making overall transmission measurements on the Reference System, measuring the insertion loss of networks (or gain of amplifiers), the gain of microphone amplifiers and various transmission measurements on local telephone circuits. This last facility is useful for checking the performance of the local telephone circuits, which are compared with the Reference System.

The whole equipment is mounted on a standard 6 ft. 6 in. rack (which is fitted with a wheeled chassis).

Acoustic Test Gear.

The electro-acoustic elements have been chosen for stability but it cannot be assumed that they will not vary during the life of the ARAEN, particularly as a life of at least 15 years has been envisaged. Consequently a set of equipment for checking the performance of both microphone and receivers has been provided.

The check need not necessarily be an absolute calibration and some more convenient method can be used. The method must, of course, be sensitive to any change in the absolute response of the microphone or receiver. These principles have been followed in the design of the test gear, where the microphones are calibrated on a coupler device and the receivers on an artificial ear. The sound pressures inside the coupler and the artificial ear are measured by a probe-tube microphone which must itself be calibrated on some absolute standard of sound pressure. The absolute standard used with this equipment is a stationary-wave tube and Rayleigh disk.

The acoustic equipment is mounted on three racks with a table for the Rayleigh disk apparatus and the stationary-wave tube. The plan of the equipment in Fig. 3 shows the arrangement of the racks and the table for the stationary-wave tube and Rayleigh disk apparatus. A further table is placed between the racks for the convenience of the operator when recording results.

The Rayleigh disk equipment[7] is used solely for measuring the sensitivity of the probe-tube microphones. These consist of a high-quality moving-coil microphone mounted in a heavy metal case, with a hypodermic tube (0·03 in. internal diameter) which forms the path between the microphone diaphragm and the sound field. The particular advantage of this type of microphone is that the tip of the probe causes only a negligible amount of disturbance when inserted in any sound field. The stationary-wave tube used with the Rayleigh disk equipment is a rigid-walled metal tube closed at one end with a moving-coil receiver, and at the other with a plate containing a small opening which will allow the insertion of the microphone probe tube.

If a voltage of suitable frequency is applied to the receiver a stationary sound wave is produced in the tube with a pressure maximum at the plate where the probe tube is inserted and a velocity maximum at the

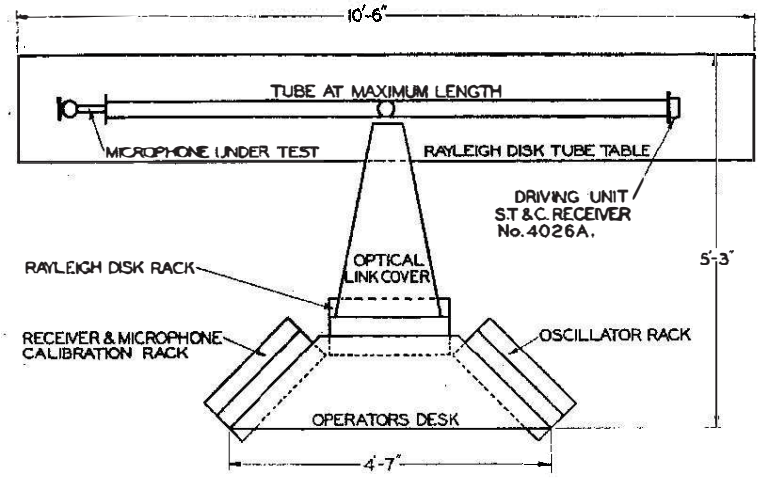


FIG. 3.—PLAN OF MICROPHONE AND RECEIVER CALIBRATION EQUIPMENT.

centre of the tube. The Rayleigh disk is suspended at the centre of the tube with its plane at 45° to the axis. When a sound wave exists in the tube, the disk rotates through a small angle which is dependent on the air-particle velocity, and this is in turn related to the sound pressure at the end of the tube. By a lamp and mirror system the angular rotation is displayed on a screen mounted on the centre rack of the equipment. From the angular displacement of the Rayleigh disk it is possible to calculate the sound pressure applied to the probe-tube microphone. The E.M.F. produced by the microphone can be compared with a known voltage of the same frequency by means of an amplifier and voltmeter system. The known voltage is obtained from an accurate potential divider which is fed from the oscillator supplying the receiver (an oscillator similar to that used in the transmission measuring equipment). The output of the oscillator is itself measured with a thermo-couple instrument which can readily be calibrated against a D.C. sub-standard instrument. The voltmeter associated with the amplifier system (actually the amplifiers used in the Reference System sending end) is a Tester RP790 which in this case is only used as an indicator of equal values. All these operations can be made in a simple manner with the switching arrangements built into the equipment.

To calibrate the microphones used with the Reference System a closed coupler device is employed. This is a small open cylinder with a high-quality receiver (S.T.C. 4026A) clamped on one end as a source of sound, and the microphone under test clamped on the other. (To do this the grille of the microphone has to be removed.) The tip of the probe-tube microphone is inserted through the wall of the coupler and placed in an accurately defined position close to the centre of the diaphragm of the microphone under test. The measurement of the sensitivity of the microphone is made by comparing, at various frequencies, the output of the probe-tube and the test microphones. The comparison is carried out by adjusting an attenuator in the test microphone circuit until both give the same deflection on the Tester RP790. The attenuator readings then represent the difference in sensitivity of the two microphones and their associated circuits, consequently the calibration of the Reference System microphone when used under the particular conditions imposed by the coupler, can be derived from the calibration of the probe-tube microphone. A calibration under the conditions of the coupler though not the conditions of use is sufficient to check that the microphone has not altered in sensitivity at any frequency.

Receivers are calibrated on the artificial ear, again with the use of the probe-tube microphone. The artificial ear[8] is used to close the receiver with an acoustical impedance which has been designed to lie within the range of impedances observed on male ears. The receiver is placed centrally on the artificial ear and sealed acoustically with a smear of vaseline. A known voltage is applied to the receiver terminals and the sound pressure developed in the artificial-ear cavity is measured by the probe-tube microphone inserted at a suitable point. The output of the probe-tube microphone is measured in the same way as when it was itself being calibrated. This enables the response of the receiver on the artificial ear to be derived from the probe-tube microphone characteristic. The response obtained depends on the position of the probe-tube microphone and for these measurements the entrance of the probe-tube is placed at the bottom of the artificial-ear cavity.

INSTALLATION OF THE EQUIPMENT AT THE C.C.I.F. LABORATORY

Three Reference Systems and two sets of associated equipment were constructed at Dollis Hill, and one of these systems and one set of associated equipment were sent to the C.C.I.F. Laboratory at Geneva.

The equipment was erected in three groups, consisting of the Reference System, the noise and intercommunication equipment, and the acoustic test gear. The first two groups were placed in the room which also contains the old SFERT system, whilst the acoustic test gear was placed in a separate room. The major part of the Reference System is mounted on two standard 6 ft. 6 in. racks, which are placed immediately behind the table used for the talking position (see Fig. 4). The talker sits at this table which contains the stands for the microphone of the Reference System and for handsets of any telephone sets under test; a steel cabinet containing various controls for the system together with a loudspeaker panel for the intercommunication system is mounted beside the operator. The remainder of the Reference System is located at the listening position, which is in a sound-proof room, situated at some distance from the talking position.

Connections between the Reference System and the listening position are made by a number of single-pair cables which are terminated on U-link sockets close to the talking and listening positions. The circuits are

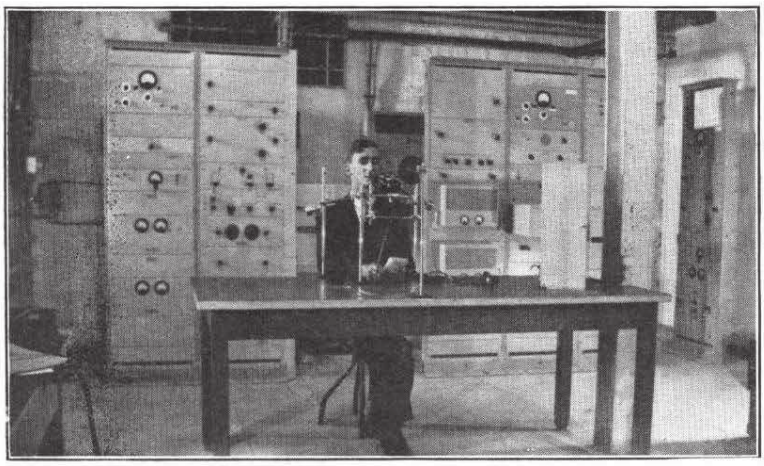


FIG. 4.—THE TALKER'S TABLE AND ADJACENT REFERENCE SYSTEM RACKS.

then wired through a U-link break point to their appropriate apparatus. The local wiring is carried out in special cable with an insulated, braided copper screen.

A number of circuits between the talking and listening positions is also required for apparatus which is being tested against the Reference System. The C.C.I.F. laboratory staff, therefore, installed a 25-pair cable at the same time as the circuits for the Reference System. This cable, which has individually screened pairs, is terminated on the same U-link panels as the others. All these cables are run at ceiling height on light racking which was built in sections at Dollis Hill and then assembled as required on site.

The noise generation and intercommunication equipment is mounted on three racks which are placed close to the talking position. Connections between these racks and the listening position are made in the same way as those for the Reference System.

The acoustic test gear does not require frequent use and has no external connections except one to the A.C. mains supply. As the room containing the Reference System was already full, the test gear was placed in a separate room. The equipment consists of three racks, and a table to contain the Rayleigh disk apparatus. This needs an extremely rigid table of rather unusual proportions and one was made specially from welded stainless steel tube and black plastic sheet. This equipment was more difficult to erect than the other as both the racks and the table had to be fixed accurately in position.

The whole work of installation was carried out without any major difficulties arising, though the structure of the building caused some minor problems in the installation which were dealt with satisfactorily by the Post Office staff carrying out the work. The staff of the C.C.I.F. laboratory provided valuable assistance both in making preparations before the arrival of the equipment and in assisting the Post Office staff during the installation.

Conclusion.

The ARAEN installed at the C.C.I.F. laboratory is at present (January 1950) in use for training C.C.I.F. laboratory staff on articulation testing in preparation for the 8th Series of Tests of the laboratory which deals with the development of the A.E.N. method of rating. A number of questions on the technique of use can only be finally decided at the stage when the 4th C.E. specifies the complete details of the A.E.N. method; the 8th Series of Tests is itself the main means of providing data on which these decisions can be based. These decisions are concerned with such points as the use of room noise at the receiving end and the precise method of specifying the talking level; they will not involve more than very slight changes in the ARAEN itself.

REFERENCES

[1] "C.C.I.F. Meetings May and July, 1949," *P.O.E.E.J.*, 1949, Vol. 42, p. 168.

[2] Martin, W. H., and Gray, C. H. G. "Master Reference System for Telephone Transmission," *B.S.T.J.*, 1929, Vol. 8, p. 536.

[3] C.C.I.F. White Book (1934), Tome IV, p. 263.

[4] C.C.I.F. "Programme Général d'Interconnexion Téléphonique en Europe (1947-1952)," p. 26.

[5] Hoth, D. F. "Room Noise Spectra at Subscribers' Telephone Locations," *Journal of Acoustical Society of America*, 1941, Vol. 12, p. 499.

[6] American Standards Association. "Sound Level Meters for Measurement of Noise and Other Sounds," Standard No. Z24.3—1944.

[7] West, W. "Acoustical Engineering" (Pitman, 1932), p. 138.

[8] Medical Research Council, Special Report Series, No. 261. "Hearing Aids and Audiometers" (H.M. Stationery Office, 1947), p. 37.

Book Review

"Numerical Exercises in Electrical Wiring. W. S. Ibbetson. E. & F. N. Spon, Ltd. 87 pp. 5s.

A companion book to the author's *Electric Wiring Theory and Practice*. In the earlier editions of the latter work, exercises were included, but these have been omitted from the later editions owing to space limitations. The present book fills the gap. The arrangement and numbering of chapters follow that of the parent book and a total of over 400 numerical exercises has been collected from various sources, such as City & Guilds, Ministry of Transport and Institution of Marine Engineers' examinations. The exercises are essentially practical in character, as would be expected from the nature of the subject, and the student wiremen cannot but profit by working the examples. An introductory chapter of exercises on general mathematical principles should reassure the non-mathematically inclined that only elementary mathematics is necessary for the solution of the wiring problems presented. General data and trigonometrical tables are included and also answers to the problems.

W. T. G.

Improved Method of Cable Buoy Recovery

U.D.C. 621.315.29

IT may be of interest to readers to learn of a nautical improvement in cable operations which has been satisfactorily developed in H.M.T.S. *Monarch* for the recovery of buoys at sea, in deep water (500 to 3,000 fathoms).

The method in the past has been to approach the buoy to within a distance of about half a cable (100 yards) and then lower a boat which pulled to the buoy, taking with it the end of a 3 × 3 wire rope. This was attached to the buoy moorings (a stray end of which was led to the upper part of the buoy for the purpose). The slip-hook attachment holding the moorings to the buoy was then "knocked up" with a hammer and the buoy was released from the moorings which then led directly on board the cable ship via the 3 × 3 rope previously mentioned. The boat then pulled back to the ship towing the cable buoy, and boat and buoy were hoisted on board. The moorings were picked up in the usual manner over the bow sheaves.

This method whilst satisfactory to some extent had many disadvantages, not the least of which were the dangers to the boats' crews encountered in lowering and hoisting boats in bad weather. This factor alone frequently made it impossible to proceed with cable operations until the weather and sea conditions eased, and much time has been lost on this account in the past.

The improved method developed in *Monarch* overcomes these troubles and has been most successfully used during the past two years in all weather and sea conditions. Briefly it consists of steaming right up alongside the buoy and getting hold of the "tail" with a light grapnel and line from the deck of the ship. This tail is the free end of the buoy moorings extended to a length of about 30 fathoms and fitted with cork floats and metal "pellet" floats, which is left free to float out from the buoy when it is originally streamed, and serves, additionally, as a current direction indicator when approaching the buoy to recover it.

Having recovered the tail with the light grapnel and line it is picked up to the deck and shackled to a heavy wire rope led over specially constructed lifting leads fitted to the bulwarks, and then to the forward capstan. Upon heaving away on the capstan the weight of the moorings is taken directly and the buoy comes up on them to deck level. It is then all clear of the seas and can be got at in comparative comfort to shackle on the 6 × 3 rope which has been led from the cable gear to the bow sheaves and then back outboard to the buoy-lifting sheaves.

When this has been shackled up it is slipped from the buoy and on picking up on the cable gear the moorings are transferred to the bow sheaves and picked up and the buoy, which is left at the buoy-lifting sheave, is unrigged and taken inboard.

J. P. F. B.

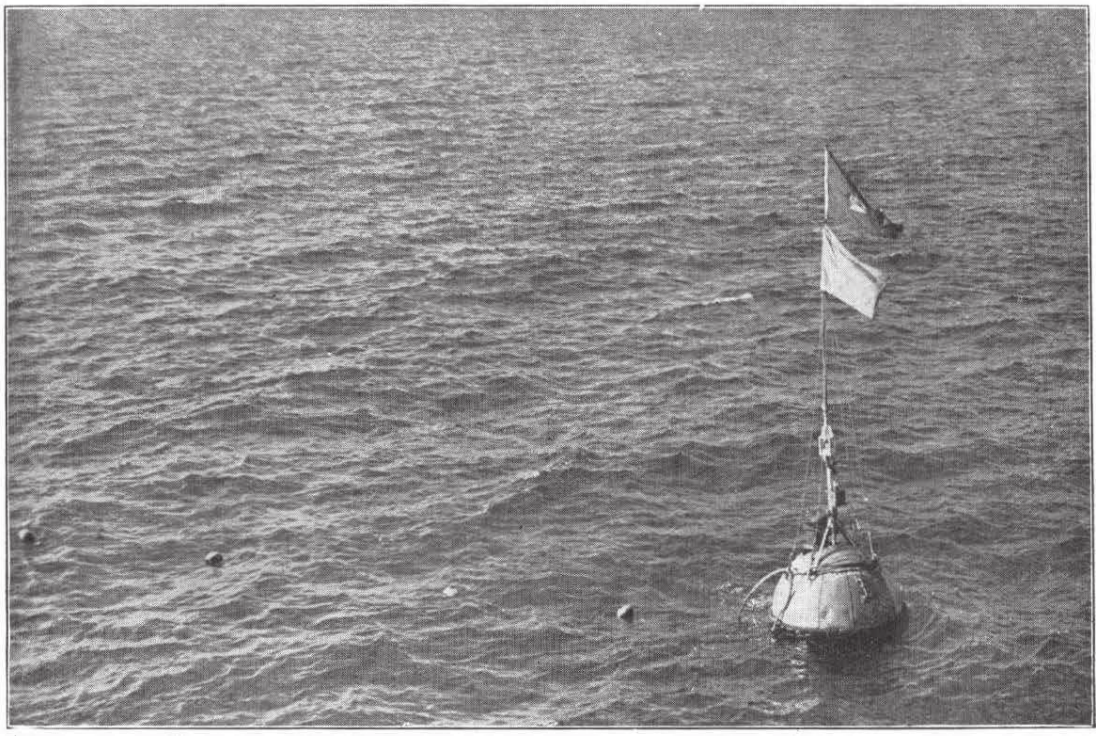


FIG. 1.—CABLE BUOY WITH "TAIL." CURRENT DIRECTION OPPOSED TO WIND DIRECTION AS SHOWN BY FLAGS.

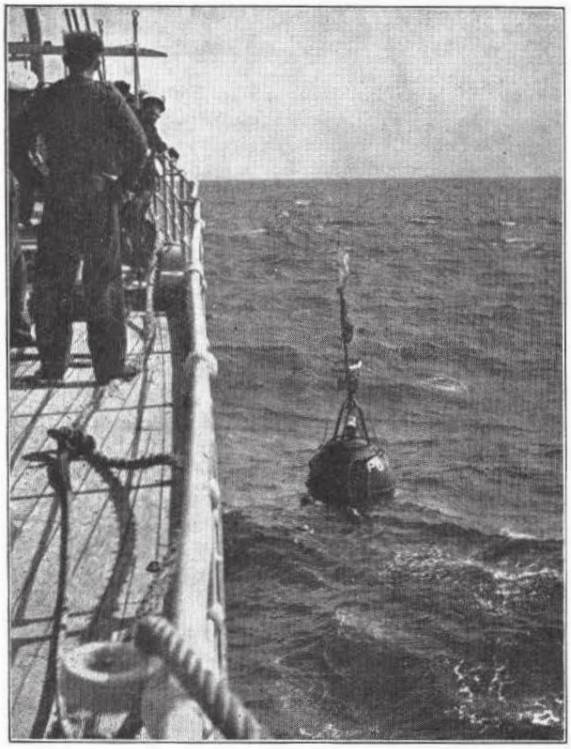


FIG. 2.—APPROACHING BUOY BEFORE RECOVERY

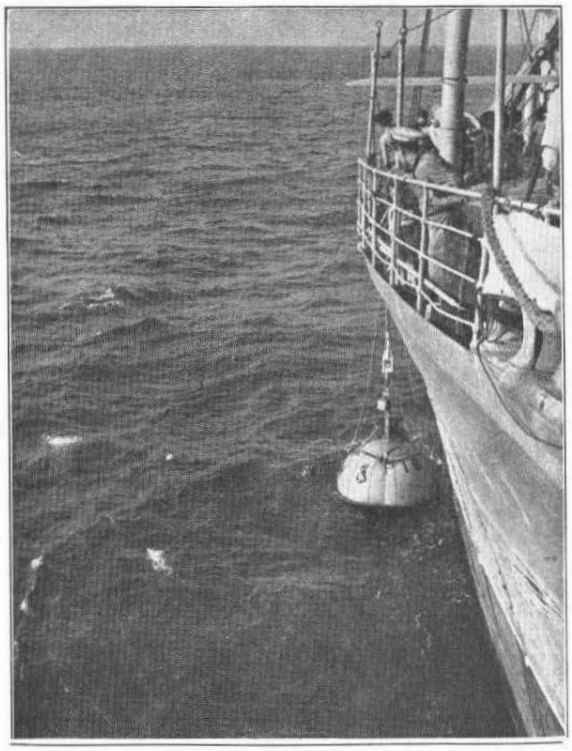


FIG. 3.—VIEW, LOOKING AFT, OF BUOY COMING IN ALONGSIDE SHIP AND SEAMEN HOOKING "TAIL" WITH GRAPNELS.

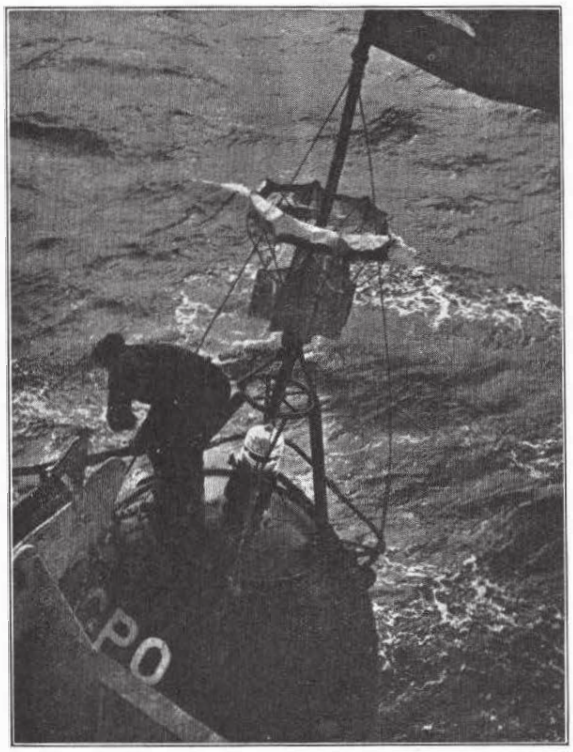


FIG. 4.—SEAMAN SHACKLING 6 × 3 ROPE FROM BOW SHEAVE BEFORE MOORINGS ARE SLIPPED FROM BUOY AT SIDE SHEAVE.

FIG. 5.—BUOY HOISTED TO DECK LEVEL ON SPECIAL SHEAVE.

A Survey of Modern Radio Valves

Part 4.—Transmitting Valves for use up to 30 Mc/s.

K. D. BOMFORD, M.Sc., A.M.I.E.E., and A. H. F. HUNT

U.D.C. 621.385

The principles of operation of transmitting valves for use up to about 30 Mc/s are generally similar to those applicable to the corresponding receiving valves. The discussion in this article, therefore, is mainly confined to questions of design and construction, with particular reference to the materials used for envelopes and electrodes and the means adopted for disposal of heat liberated during valve operation.

Introduction.

SOME of the basic phenomena of the primary and secondary emission of electrons, and of electrons in transit have been outlined in Part 2 of this series,[1] in so far as they apply to the behaviour of thermionic valves; and these properties affect the design of high-power transmitting valves just as much as they do that of the receiving valves already considered,[2] although in places the emphasis differs appreciably. This difference of emphasis arises because many of the problems in designing the larger valves are different from those encountered with receiving valves which, in turn, is due to the use of high anode voltages and to the need to dissipate large quantities of heat.

The need to avoid parasitic oscillations and to reduce stray and inherent inductance and capacitance, and considerations of space and general neatness militate against the use of large numbers of valves in parallel for handling high powers. Valves have, therefore, been developed that are individually capable of handling powers of a hundred kilowatts or more.

The development of such large valves for use on frequencies below, say, 30 Mc/s might appear to have been slow when compared with the many different ranges of receiving valves that have been produced. This is because there are many difficulties associated with high-power operation which have no counterpart at low powers, and because high-power valves are expensive and are produced in small numbers so that there is a natural reluctance to depart from a proven design.

The literature of transmitting valves is largely concerned with the need to provide for and dispose of the large quantities of heat liberated at the electrodes, mainly the anode; and the size of a transmitting valve is normally referred to in terms of the rate at which the valve can dissipate heat from the anode, i.e. its "anode dissipation." This is because there is an upper limit to the efficiency with which a valve can convert the D.C. anode supply into radio frequency power, of the order of 70 per cent., and the power handling capacity is usually limited by the anode dissipation. In the smaller valves of this class the anode, and of course the other electrodes, are enclosed in an envelope and the heat liberated must be dissipated almost entirely by radiation. In larger valves the anode forms part of the envelope and is fitted either with cooling fins through which air is forcibly circulated or with a water-jacket connected to a circulation system. Radiation of heat from the anode is then negligible but from other electrodes remains of primary importance. This subject will, however, be considered in more detail when describing different types of valve.

Transmitting valves for the frequencies concerned in this article are made in the form of triodes, tetrodes, i.e. screen-grid valves, and pentodes, but the first-named include the great majority of valves. The principles of operation are generally identical with those of the corresponding receiving valves except that in transmitting valves the grid must be driven well positive during part of each cycle in order that the peak anode current may approach the maximum available emission from the filament, resulting in the flow of appreciable grid current. To avoid repetition, therefore, it is proposed to discuss only those matters that are peculiar to transmitting valves, questions largely of design and construction.

Constructional Features

Filament Material.

In high-power valves the large potential difference between the anode and cathode gives rise to much higher positive-ion arrival velocities than an oxide-coated cathode can withstand, and the more robust but less efficient thoriated-tungsten and pure tungsten filament cathodes are therefore used. In recent years the achievement and maintenance under operating conditions of a higher degree of vacuum than has hitherto been possible has led to a rise in the permissible D.C. anode voltage for valves using thoriated-tungsten filaments. Nevertheless, it is still necessary to use pure tungsten for the filament material when anode supply voltages much above 10,000 volts are used. Relating filament material to methods of cooling it usually happens that thoriated-tungsten is used in radiation-cooled valves while pure tungsten is used in valves of such high power that forced cooling is needed.

Glass Envelopes.

The properties desirable in glass used for the envelopes of transmitting valves are high insulation resistance, low radio-frequency power factor, high resistance to thermal shock, high thermal transparency, low thermal expansion and, last but not least, high softening temperature. Common soft glass, i.e. lead-soda or lead-soda-potash glass, is relatively cheap and has most of these properties, although its softening temperature is only 850°K and its thermal expansion is comparatively high. Such a glass is quite suitable for lower power valves with

[1] *P.O.E.E.J.*, Vol. 42, p. 118.

[2] *P.O.E.E.J.*, Vol. 42, p. 201.

small leading-through wires for the electrodes. The permissible heat dissipation can be increased by the use of either a larger bulb or a harder glass such as pyrex, or borosilicate, with a higher softening point than soda-glass, i.e. about 980°K. Unfortunately, hard glasses have the disadvantage of fairly high annealing temperatures and are more difficult to manipulate ; in addition, they are not so transparent to radiant heat as soda-glass. The power factor of glass increases with temperature and in very strong radio-frequency fields the dielectric loss may cause sufficient local heating at frequencies of the order of 30 Mc/s to soften the envelope.

The risk of envelope softening places a limit on the permissible anode temperature in glass valves and restricts the power dissipation by radiation to between 25 and 60 watts per sq. in. of anode surface, depending upon the anode material used. An attempt to increase the power dissipation by an arbitrary increase in anode dimensions leads to difficulties in the design of the filament, which becomes unnecessarily long for the emission requirements. It is therefore unusual for glass envelope valves to have power ratings exceeding about 1·0 kW.

Silica Envelopes.

An increase in permissible power dissipation to about 5 kW, without forced cooling, is obtained by using silica envelopes in place of glass. The much higher softening temperature of the envelope, in the region of 2,000°K, allows the working temperature of the anode to be raised, and greater powers to be dissipated for the same bulb size ; it also allows the valve to be pumped and de-gassed at very high temperatures, resulting in more complete elimination of adsorbed gases and a higher degree of vacuum. One effect of the improved vacuum is to reduce positive-ion bombardment of the filament ; this allows a thoriated-tungsten filament to be used when the anode voltage is higher than is permissible with the same type of filament in a glass envelope valve.

For many years, however, a disadvantage of silica valves was the difficulty of producing seals[3] that could withstand the high temperatures due to the relatively large inter-electrode R.F. currents that occur in operation at high frequencies. Reliable direct metal-to-silica joints were made only with difficulty and the earlier silica valves used soft glass seals.

In recent valves this temperature limitation has been overcome by using a seal of tungsten-coated molybdenum with hard glass between the metal and silica and the maximum frequency of operation has been raised to between 20 and 50 Mc/s.

Glass-to-Metal Seals.

A great advance in the design of high-power valves was made when it became possible to dissipate heat from the anode by bringing a cooling medium into direct contact with it. This can only be achieved conveniently by making the metal anode form part of the envelope, and requires a large metal-to-glass seal. In the Housekeeper seal, which was first introduced in 1922, the difficulty of the difference in the coefficients of expansion of glass and metal is overcome by a process that involves machining the end of a tubular copper anode to a fine edge and fusing the glass envelope to the copper, using borax as a flux. The thin copper edge can be made sufficiently flexible to withstand the differential expansion stresses without sacrificing the strength needed to withstand the atmospheric pressure, which may amount to several hundred pounds in the largest valves. The temperature of the Housekeeper type of seal should not exceed about 470°K under working conditions.

An alternative seal has been developed using an alloy ring with a thermal expansion coefficient more closely matching that of the glass. An intermediate alloy ring of copper-plated nickel-iron is sealed to the glass, using borax as a flux, and brazed to the copper anode, and it is interesting to note that the latter joint gave more difficulty in the initial development. The copper plating on the alloy increases adhesion to the glass and lowers the resistance to high-frequency eddy currents which would otherwise overheat the ring. Seals of both types have been made up to rather more than 5 in. diameter.

Protection from strong electric fields and excessive dielectric stresses set up by the sharp metal edge is provided by internal and external guard rings, the external guard ring often serving as an air blast pipe for cooling the seal.

Electrode Materials.

The materials used for the anodes in transmitting valves depend on whether the valves are radiation-cooled or forced-cooled, i.e. whether the anode is inside the envelope, or forms part of it. In radiation-cooled valves the anodes are commonly made of tantalum or molybdenum as these metals have the advantage of being relatively free from occluded gases. Their radiating properties are often improved by sand blasting the surface of the anode or by providing cooling fins inside the valve. Certain of these metals will, when very hot, absorb gases in sufficient quantity to make them extremely useful for maintaining a high degree of vacuum. This " clean-up " capability is specially desirable because getters such as magnesium and barium cannot be used in transmitting valves on account of their liability to volatilise at the high temperatures involved. Carbon anodes are also used in some cases.

The vapour pressure of the anode material affects the maximum temperature that can be permitted in operation or during pumping, because of the possibility of metal becoming deposited on the insulating surfaces. In this respect tungsten and tantalum are very satisfactory, but nickel, which is otherwise a very suitable material, has a high vapour pressure and its use is therefore restricted to valves of low and moderate ratings. In radiation-cooled valves the anode surface is commonly coated with amorphous carbon to improve the thermal emissivity.

Where the anode forms part of the valve envelope heat is removed from it by conduction to the cooling

[3] The junction between the metal of the leading-through connections or the electrodes, and the glass or silica envelope is called a " seal."

fins or the cooling water, and the working temperature is low. In such valves good thermal conductivity is of great importance and the anode material should be suitable for sealing to the glass portion of the envelope; for these reasons copper is used almost exclusively.

The grid material also must be capable of withstanding high operating temperatures, partly because there is appreciable grid current, and partly because of the proximity of the heated filament and the fact that the surrounding hot anode surface impedes heat radiation from the grid. Tungsten, tantalum or molybdenum are commonly used and the surface may be carbonised to improve the heat radiation and also to reduce grid secondary emission. Grid structures using these metals do not distort at high temperatures, while all three are sufficiently ductile for drawing into fine wire for the grid winding.

Valve Types

Radiation-cooled Valves.

As an illustration of modern radiation-cooled valve construction, Fig. 1 shows a 1·5-kW valve in a recently

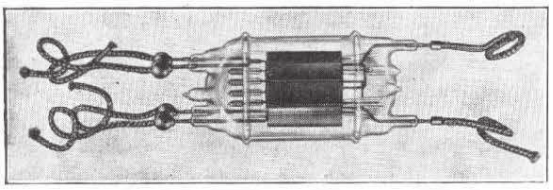


Fig. 1.—1·5-kW Silica Envelope Valve.

introduced series of silica triodes for use up to at least 30 Mc/s. Two leads each are provided for the anode and grid to assist in keeping the temperature of the seals low and it will also be noticed that the envelope is shaped so that the seals are spaced well away from the hot anode.

It is worth noting that the development of valves for this range has been stimulated by the widespread adoption of dielectric and induction heating in industrial processes, for which the conditions of operation, being intermittent and not subject to the same rigid control, are generally more severe than in radio transmitters.

Water-Cooled Valves.

Liquid cooling is the most effective means of transferring large quantities of heat from the anode; and if certain precautions are observed water forms a very convenient cooling fluid and enables anode dissipations exceeding 1 kW per sq. in. of anode surface to be attained. The velocity of the water must be sufficient to ensure turbulence so that any steam bubbles formed do not adhere to the outside of the anode and allow local overheating, and the space between the anode and water jacket may be constricted to increase the water velocity and reduce the thickness of the stagnant layer of water that tends to form at the surface of the anode wall. The rate of flow required is directly proportional to the power dissipation for a given temperature rise. The heat transfer from anode to water is more efficient when incipient boiling occurs, and the temperature of the anode wall may therefore exceed that of boiling water.

Where the water supply is hard and scale is deposited the anode temperature is liable to rise sufficiently to result in overheating of the anode-to-glass seal. To counteract this the seal is commonly cooled by some auxiliary system, such as a special air blast, and the water supply is required to conform to a minimum standard of purity. A satisfactory standard is that the dissolved solids shall not exceed 10 parts per 100,000 and the conductivity shall not exceed 100 reciprocal megohms per cm. cube, which usually entails the use of distilled water. The rate of flow is usually between 0·25 and 0·4 gal./min. per kW of anode dissipation, which is equivalent to a temperature rise from inlet to outlet jacket of less than 15°C and usually requires a pressure of 40-50 lb./sq. in.

The jacket is sometimes made integral with the valve and may be ribbed laterally to provide a measure of flexibility and reduce mechanical stresses

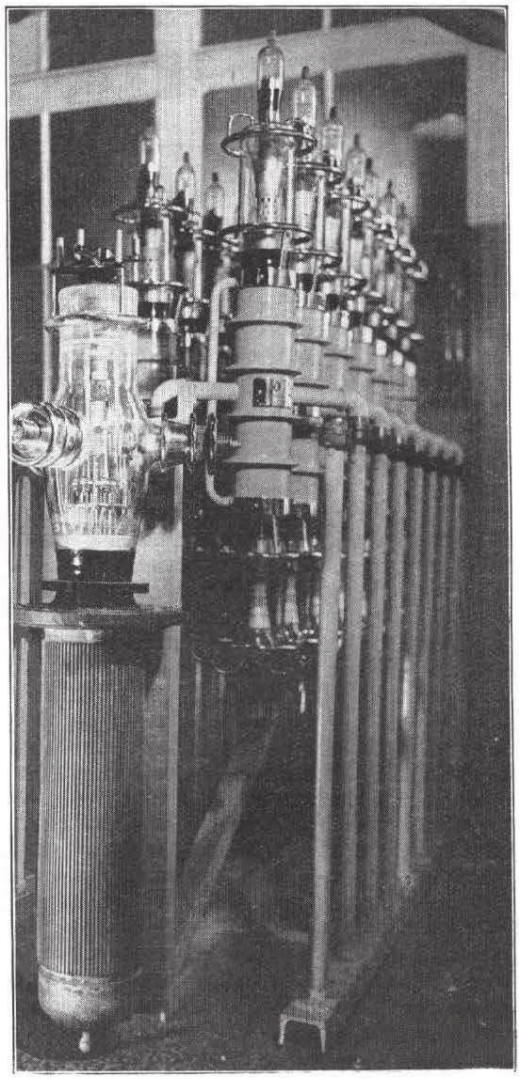


Fig. 2.—160-kW Water-Cooled Triode and a Bank of 80-kW Double-ended Water-Cooled Triodes.

due to the difference in expansion of jacket and anode. This form of jacket is used on the row of mounted

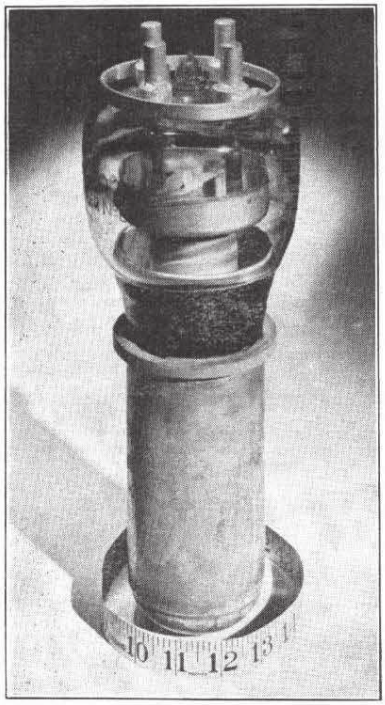


FIG. 3.—SINGLE-ENDED 20-KW WATER-COOLED TRIODE WITH THORIATED-TUNGSTEN FILAMENT.

valves shown on the right-hand side of Fig. 2. These valves are double-ended, that is grid and filament connections are led out at opposite ends, an arrangement that has an advantage from the insulation standpoint and also reduces inter-electrode capacitances, but has been superseded in short-wave valves by the single-ended arrangement which is generally more convenient for circuit layout. The 160-kW single-ended valve shown in the foreground of the photograph has a channelled anode surface to provide a greater area of contact with the cooling water.

The improved vacuum attained in modern valves has, as already mentioned, led to the use of thoriated-tungsten filaments in high-voltage valves and Fig. 3 shows a 20-kW water-cooled triode incorporating such a filament. The valve can be used at frequencies up to 30 Mc/s and has a peak usable emission of 35 amps. obtained from a thoriated-tungsten filament rated at 10V, 80amps. The maximum permissible anode supply voltage is 8 kV when the valve is subject to anode modulation, and 11 kV under other conditions. In valves of this class thoriated-tungsten filaments offer a substantial economy in heating power, equivalent to a saving of 85 per cent. or more when compared with pure tungsten filaments, and have attendant advantages in respect of the furnace effect on other electrodes and of hum arising from the modulation of the electron stream by the magnetic field due to the filament current. There is, moreover, a reduction in the mechanical forces to which the filament is subject, which are proportional to the square of the heating current, and the problem of supporting the filament is eased. Both types of filament suffer from the disadvantage that their resistance when cold is very much less than when hot, and the voltage applied initially must be reduced considerably below the normal value to avoid mechanical distortion due to excessive current. A limit of 150 per cent. of the normal current is sometimes stipulated for the surge current.

The water-cooled valve on the right-hand side of Fig. 4 is a good example of modern high-power transmitting valve practice and illustrates the general trend of development that has been brought about by the need for extending the upper frequency limit of operation. This limit is determined primarily by two factors. the physical dimensions of the valve and the current-carrying capacity of the grid seal. The construction should be compared with that of the earlier valves of comparable power rating shown in Fig. 5, in which side-entry grid seals are used. In the more modern valve the grid is supported on one end of a cylinder at the opposite end of which there is a metal flange sealed to the glass envelope. This form of construction results in a very low inductance of the grid lead and allows large grid currents to be handled without difficulty. The principle of supporting electrodes directly from the seals is important

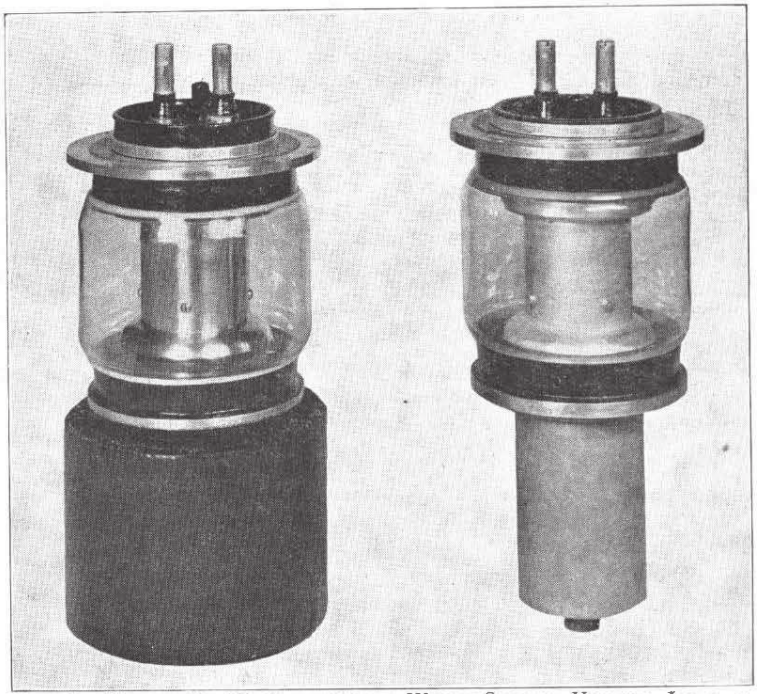


FIG. 4.—RIGHT, 20-KW SHORT-WAVE WATER-COOLED VALVE; LEFT, A FORCED-AIR-BLAST VERSION CAPABLE OF 10 KW ANODE DISSIPATION.

in so far as it dispenses with insulating supports in the more active parts of the valve.

Air-Cooled Valves.

The larger type of modern forced-air-cooled valve can be regarded as having evolved from the smaller

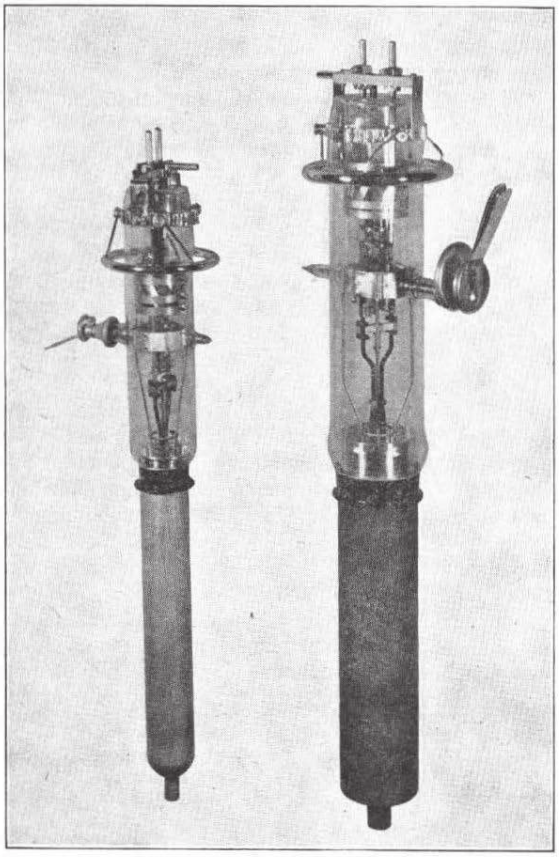


FIG. 5.—18-kW TRIODE (RIGHT) AND 12-kW TRIODE, WITH SIDE-ENTRY GRID SEALS.

single-ended water-cooled valve. The construction is basically the same, the water-jacket being replaced by a radiator or cooler usually of the type shown in Fig. 6 and comprising a copper sleeve to which are brazed a large number of radial, blackened-copper cooling fins. For certain valves the system of cooling is optional in so far as a water-jacket or cooler may be supplied as desired. The radio frequency characteristics of the valve are unaffected by the change, but the large anode structure necessary for air cooling results in a higher anode-earth capacitance. A dissipation of about 4 watts per sq. in. of cooling fin surface is reasonable with a circulating air system, usually suction, of 60-100 cu. ft./min. per kW of total anode dissipation. Such a system keeps the temperature of the cooler below about 160°C, which corresponds to a dissipation of 200-400 watts per sq. in. of effective anode surface, that is, equivalent to a little less than one-half the dissipation that can be allowed with water cooling. The temperature of the outlet air is about 15°C above ambient and the maximum outlet temperature is often specified as 45°C. Valves of the type shown in Fig. 6 have been developed for anode dissipations up to about 20 kW, which is sufficient for the majority of commercial applications. Another form of cooler sometimes adopted comprises several crimped concentric sheaths.

As in water-cooled valves, the temperature rise of the circulated cooling medium can be used as a measure of the power dissipation at the anode, but it is not practicable to calculate the relationship for air coolers and a calibration is made with the valve running under static conditions with known anode dissipations.

Air-cooling systems of the above types have great possibilities. There appears to be no reason why the same advances should not be made in cooling valves as have been made in the cooling of aero engines by using carefully designed ducts that ensure the maximum heat transfer with the minimum resistance to air flow, and there is no reason why an air-cooling system on these principles should not be extended eventually to valves of the highest power ratings now in use. It may also be applied to relatively low-power valves with advantage if, by so doing, the physical dimensions of the valve can be

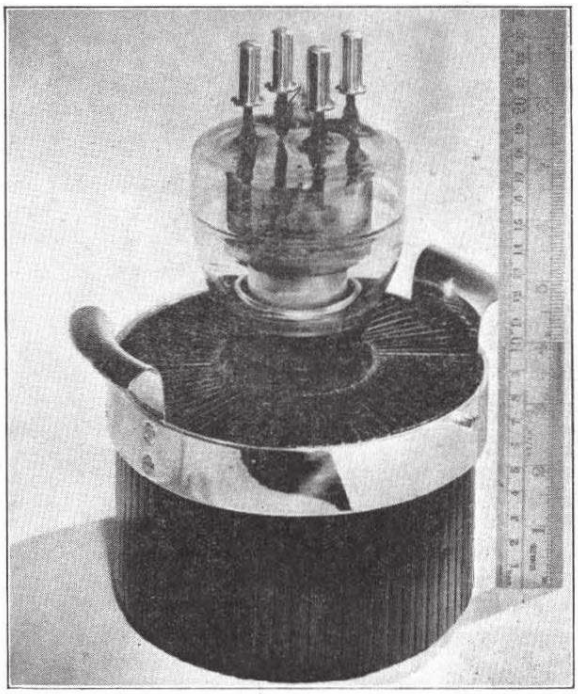


FIG. 6.—FORCED-AIR-COOLED TRIODE, 4·5 kW ANODE DISSIPATION.

reduced and the efficiency at high frequencies raised. Fig. 7 is an example of a valve of 1 kW maximum anode dissipation which by virtue of its small size is capable of effective operation at frequencies up to 100 Mc/s. An open-ended cylinder is used to support the grid and three connections from it are led out to ensure that the inductance is low. The filament in this case is centre-tapped. The valve requires an air-flow of 80 cu. ft./min. at a pressure of 2 in. of water.

High-power valves are relatively fragile, the seals being the weakest points because of the relatively heavy electrode assemblies that they are required to

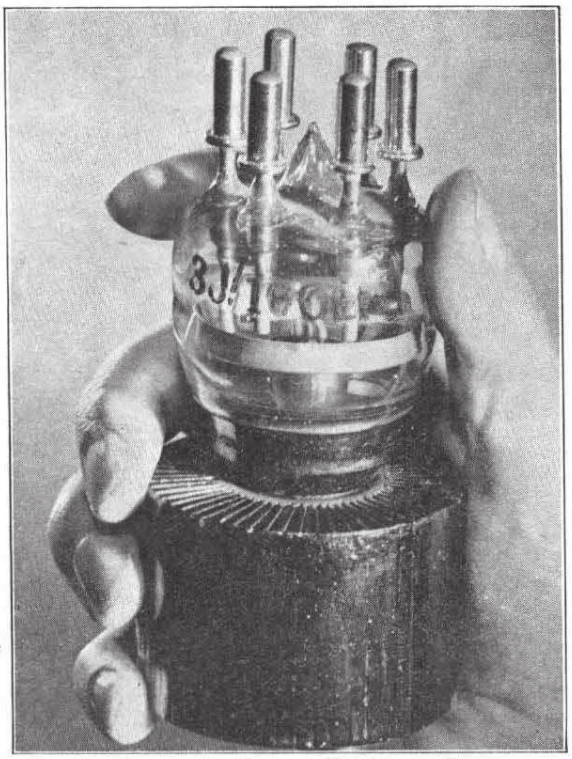


FIG. 7.—FORCED-AIR-COOLED TRIODE, 1 kW ANODE DISSIPATION.

carry. The problem of ensuring safe transport therefore becomes a very real one, especially in view of the rising demand for valves of this category for industrial R.F. heating.

VALVE LIFE

The replacement of high-power valves is a major item in the cost of running transmitting stations and the length of life is therefore of great importance. Unlike the receiving type of valve with its random failure characteristics, the life of a transmitting valve can be predicted with considerable accuracy. This is because, neglecting accidents, the life is almost always limited by the evaporation of tungsten from the filament, or thorium, when thoriated-tungsten filaments are used ; all other causes of failure have been virtually eliminated by careful design and construction, and by rigid control of materials. Tungsten filaments fail consistently when the diameter is reduced by evaporation to about 90 per cent. of its original value. The actual failure occurs when a short length of the filament locally overheats ; the effect is cumulative and rapidly leads to a complete burn-out at this point. The rate of evaporation is independent of the diameter and therefore the life is directly proportional to the diameter of the filament.[4]

[4] " The Development of Large Radio Transmitting Valves." *Marconi Review*, 1936, No. 61, p. 6.

Data are available that enable the life of a filament to be calculated when the dimensions and operating temperature are known and the valve life is therefore predictable and to a certain extent within the control of the designer.

In a given type of valve with a given emission requirement the variables affecting life are therefore filament diameter and temperature. For the same emission a filament of large diameter requires more power to maintain it at the required operating temperature than one of small diameter, but the latter has the shorter life. There is, consequently, an optimum diameter determined by the replacement cost of the valve and the cost of the filament heating power. Practical considerations also influence the final choice of the filament diameter, but, generally speaking, transmitting valves are economic when the designed life is in the region of 5,000-10,000 hours ; nevertheless, by carefully regulating the filament voltage on the lines indicated below a life of about 20,000 hours may be nearer the average obtained.

Tungsten filaments are rated on an emission basis, that is the filament voltage is specified for the required emission for each individual valve. It is imperative to adhere strictly to this voltage if the design life is to be achieved, and a 5 per cent. increase in voltage will roughly halve the life ; conversely a 5 per cent. decrease in voltage will double the life at the cost of decreased performance. In practice the filament is often underrun slightly during the beginning of its life, and the voltage is increased gradually to maintain constant emission. The life will then be nearly as long as if the filament voltage had been maintained constant and the progressive reduction in emission had been tolerated.

The above considerations do not apply to thoriated-tungsten filaments, which suffer negligible evaporation in the course of their effective life and depend for their operation upon the maintenance of an active surface layer and a balance between evaporation and diffusion of thorium. Operation of the filament at a reduced voltage then has the effect of shortening the life.

Future Developments.

It is always difficult to predict the future but there are indications that valves with silica envelopes may become more widely used for radiation-cooled valves.

Improvements in exhaust technique may eventually lead to the use of thoriated-tungsten filaments in transmitting valves of the highest powers and so render the tungsten filament obsolete. The possibility exists also of extending forced-air-cooling systems to such valves but the difficulty of reducing the accompanying noise remains to be solved.

Acknowledgments.

The illustrations of transmitting valves used in this article were kindly supplied by Standard Telephones & Cables, Ltd. (Figs. **2**, **3**, **6** and **7**), the General Electric Company, Ltd. (Figs. **4** and **5**), and the Mullard Wireless Service Company, Ltd. (Fig. **1**).

The Recovery of two Timber Lattice Masts

CAPT. S. HELM, A.M.I.E.E.

U.D.C. 621.315.668.1

The author gives a brief account of an unusual work entailing the dismantling of two timber lattice masts, one 240 ft. and the other 140 ft. high. The recovery work yielded about 60 tons of good quality timber, suitable for conversion into a variety of line stores.

Introduction.

TWO wooden self-supporting lattice masts were recently purchased by the Engineering Department for use of the recovered sections for pole-arms, stay-blocks, guards and other line stores. Both masts, which had been erected 7 years, were originally 240 ft. high, but one had been damaged by aircraft and only the lower part, of 140 ft., remained. The masts were 45 ft. wide at the base and tapered to 6 ft. at the top. The wood, which was in good condition throughout, was first quality British Columbian pine, incised and creosoted.

The masts embodied the usual horizontal and vertical bracings fixed externally and internally. Platforms were provided at 30-ft. intervals vertically and were connected by stout ladders which were the normal means of ascent. The mast legs varied in section from 10 in. by 10 in. at the base, to 4 in. by 4 in. at the top. Bracings were 7½ in. by 2½ in. at the base but reduced in section in the upper parts of the mast.

Details of typical bracings at the base appear in Fig. **1**, which also shows the general form of the 240-ft. mast in the distance.

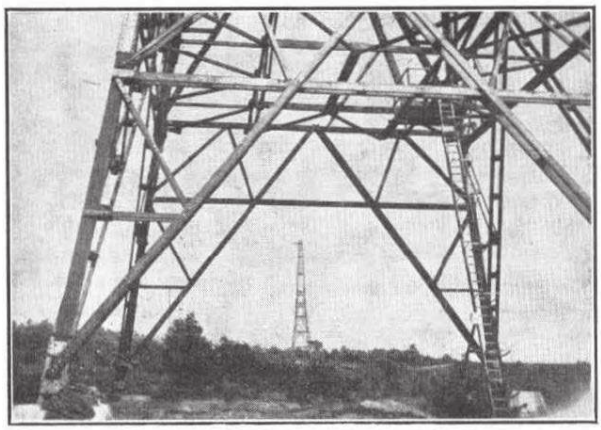


FIG. 1.—BASE OF ONE OF THE MASTS.

Tackle Used for Dismantling.

The usual rigging tackle used in mast erection consists of a derrick set up centrally inside the mast, luffing being carried out by guys run from the butt and from the derrick centre out to the mast legs. Such an arrangement enables the derrick to be manœuvred to any position for vertical lifts, but suffers from the disadvantage that the support is rather flexible and may allow the derrick to sag unduly under heavy loads. For this reason, and because the internal bracings of the mast would have prevented the free use of such a derrick it was decided to employ four separate derricks, one lashed to each leg of the mast. The derricks lashed in position are shown in Fig. **2**, and the lashing of a derrick at its butt in Fig. **3**.

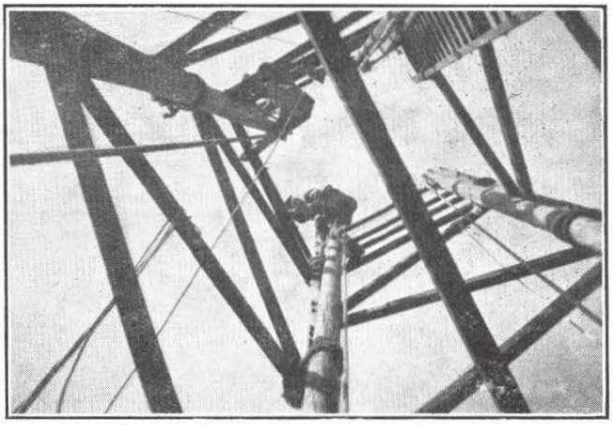


FIG. 2.—DERRICKS LASHED IN POSITION.

Each derrick was fitted with a hauling line and a 3-in. snatch block at its head. The hauling lines were taken to the ground level inside the mast bracings, and thence to guiding pulleys at the mast base. A 30-cwt Morris truck was used for hauling. The lorry traversed backwards and forwards on a straight strip of firm ground which enabled the driver to see the position of the load throughout and to take signals as required.

Dismantling Operations.

Having set up the derrick and ropes, dismantling of the upper sections was begun, single wooden sections being unbolted and passed down the centre

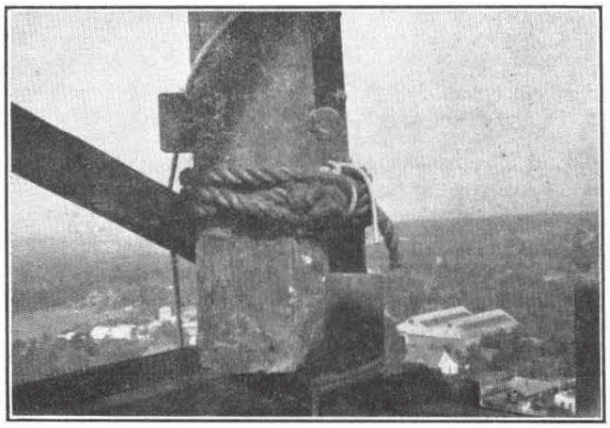


FIG. 3.—LASHING AT BUTT OF DERRICK.

of the mast by light block and line. Bolts were lowered in bags, and tools required by the riggers were sent aloft by the same means. Complete sections were then lifted clear and under the control of a light line were lowered to the ground. A top section being lowered in this manner is shown in Fig. 4. While

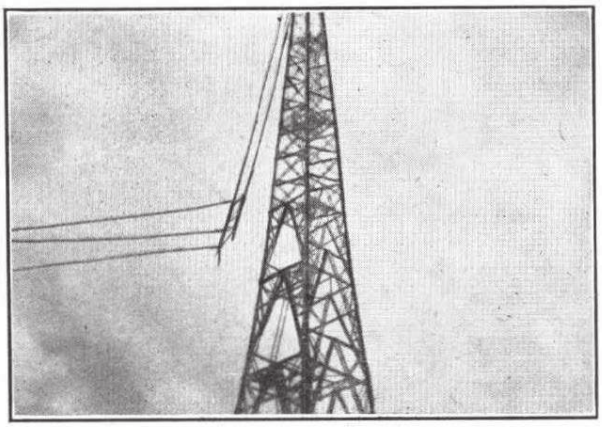


FIG. 4.—LOWERING A TOP SECTION.

overhead work continued ground staff dismantled and stacked the lowered sections. To lower the derricks a light block was rigged, coupled at the top to the highest point of the mast and hooked at the bottom into the eye bolt in the derrick butt (see Fig. 5). The load of the derrick was taken and held by two men on the nearest platform. The lower lashing of the derrick was then removed and the upper lashing slackened to a loop. The derrick was now free to be lowered to the next required position and could be relashed securely to the mast legs and bracings. All bolts were found to be in good condition and no special difficulty was met in their removal. Further, the joints were securely locked by dowels and, the timber having shrunk slightly, removal of the bolts was easily carried out. In addition to lowering the derricks it was necessary at each section to clear the ladders, platforms and internal bracings. The transfer of the ladder from its position on the platform to a lashed vertical position on the side of the mast considerably reduced the time of dismantling.

As the work progressed, the heavier sections necessitated the use of double purchase tackle from the 140-ft. level downwards. This permitted safe loads on the hauling ropes and better control during the initial lifting. When only the last section was left

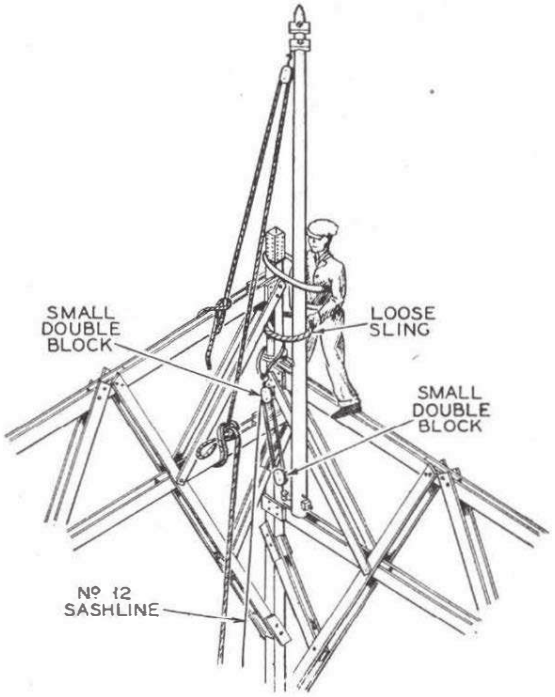


FIG. 5.—LOWERING A DERRICK.

standing the derricks, ladders and internal bracings were recovered and the site cleared.

Conclusion.

The masts were in a very exposed position overlooking the Devil's Punch Bowl, Surrey. High winds often made progress aloft arduous, but only on one day was the work suspended by bad weather. The masts yielded about 60 tons of timber which was converted into a variety of line stores as described earlier. Two external gangs from the Guildford Area were employed on the work under the direction of Mr. A. E. Ayers, five men working aloft and five on the ground. The work aloft was carried out by volunteers whose skill and courage are to be highly commended.

Book Review

"Electric Cables." Frances W. Main, M.I.E.E. Sir Isaac Pitman & Sons, Ltd. 142 pp. 52 ill. 12s. 6d.

This issue is the third edition of Mr. Main's primer on electric cables and has been re-written and brought up to date. The art and science of cable making, testing, and using has been very largely neglected by text book writers and this work fills a need. The materials, manufacture and properties of all types from bell wire to super-tension cables are dealt with, together with much practical information on selection of types, methods of laying, transmission systems, design considerations, testing and maintenance.

The author is clearly much more at home with power than with telephone cables, but as an introductory survey of a wide field the book can be confidently recommended, although the price is somewhat high for a primer.

Two small points may be mentioned: Unit Type Telephone Cable was evolved in the United States, not in Britain; and it is a pity to continue the use of the term "Polyethylene" now that B.S.I. and other authorities have agreed to call the material "Polythene."

L. G. D.

An Electronic Distortion Measuring Set for Start-stop Telegraph Signals

L. K. WHEELER, B.Sc.(Eng.), A.M.I.E.E., and R. S. TISSINGTON, B.Sc.(Eng.), A.M.I.E.E.*

U.D.C. 621.394.813 : 621.317.74

The instrument is designed to measure the distortion of teleprinter signals at a speed of 50 bauds. It can be connected to working circuits, and instruments of this type will be installed in the test desks at telegraph switching centres.

Introduction.

IN teleprinter transmission each character signal comprises seven elements; the first, or start, element is always of spacing polarity, being followed by five elements which denote the character in binary code and finally a stop signal which is always of marking polarity. The first six elements are nominally of the same (unit period) duration, whilst the stop signal may have a nominal minimum duration equal to, or greater than, the unit period according to the system (1·5 units in the British system). A succeeding character may be commenced at any instant after the expiration of the minimum stop signal period.

The cycle of the receiving mechanism of a teleprinter is initiated by the reception of the start element and terminated during the stop signal, the mechanism then remaining quiescent until the advent of the next character. Once the cycle has commenced, the process of sampling the incoming signal at the nominal mid-instants of the code elements is controlled by the machine alone. The accurate registration of the code elements depends upon the correct time relationship of the signal transitions with the start element having been preserved within certain limits during transmission.

It is evident, therefore, that a device which will indicate accurately the timing of the instants of modulation (signal polarity transitions) in a character relative to the start signal of the character, and automatically phase itself with each start signal, will be a useful instrument for the study of start-stop transmission systems and in the maintenance of circuits and equipment.

Up till this time, the only distortion measuring instrument used by the British Post Office suitable for measurement of teleprinter signals, has been the Distortion and Margin Tester (Tester TG 956/958)[1] and this has certain severe limitations. It is quite suitable for local measurements of transmitter distortion when a single character is repeated at machine speed (i.e. "plugged" speed), but its use for the accurate measurement of distortion at the end of a circuit, when fortuitous distortion is present, is difficult, and when the character repetition is at a random rate, it is impossible. This is due to the fact that it was not designed to operate in a start-stop manner, and hence the instant of the start-signal and the zero of the time scale for reading the displacements of the instants of modulation are seldom coincident.

As long ago as 1939, the need for a start-stop distortion measuring set was recognised and work on the development of an electronic instrument had commenced, but was suspended at the outbreak of war in favour of more urgent projects. Recently the development has been continued, advantage being taken of intervening advances in the use of electronic circuit technique, and has resulted in the instrument to be described. Similar measuring sets will be installed in test desks at the switching centres of the telegraph automatic switching system.

Principles of the Electronic T.D.M.S.

Since the measurement of telegraph distortion is effectively the measurement of the relative times of occurrence of electrical phenomena, an obvious means of measurement is to use a cathode-ray oscilloscope with a suitable time-base and employ means of modifying the trace to indicate the incidence of the phenomena, i.e. the instants of modulation. This is all the more suitable for a start-stop measuring device, as the effects of the inertia of moving parts and the lack of precision in the operation of clutches in an equivalent mechanical device can be avoided. Two methods of indication by varying the trace are available—variation of intensity of the beam and deflection of the beam. As two types of measurement will be required, distortion and transit time, both methods are used. Because the more frequently used facility will be that of distortion measurement, the brightening of the trace has been chosen to give this indication, as the background trace can be suppressed to leave only the bright spots visible to indicate the instants of modulation on the time scale. Deflection of the beam is employed to indicate the instants of commencement and completion of the transit period when making measurements directly on a transmitting contact assembly, i.e. without any other circuit or spark-quench connected to the tongue. Measurement is made by reading the positions of the indications from a graduated scale. This method facilitates the measurement of fortuitous distortion, which is further aided by the use of a cathode-ray tube screen with a moderately long afterglow.

The primary time-base period is made equal to the nominal time of a unit signal element (20 mS for a telegraph speed of 50 bauds) and the cathode-ray traverse is repeated for each possible signal transition during the reception of a teleprinter character (i.e. six traverses). To permit the reading of the distortion of individual instants of modulation in a character, the six traverses are mutually displaced by a suitable vertical deflection circuit, so that the general form

*Now with Telecommunications Dept., Federation of Malaya.

[1] *P.O.E.E.J.*, Vol. 26., p. 3.

of the working part of the trace is a column of six horizontal lines (see Fig. 1). The repetition rate of the

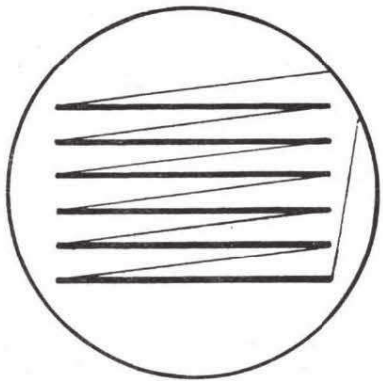


FIG. 1.—CATHODE-RAY TUBE TRACE

time-base is controlled by an oscillator which is automatically started when the start element of each character is received and stopped when the correct number of beam-traverses has occurred. When just an overall distortion measurement is required, the separation of the individual element traces may be eliminated. To facilitate the reading of the distortion of the instants of modulation, which may be either advanced or retarded relative to their correct times with respect to the start element, the commencement of the time-base cycle is delayed by a period of half a unit element (10 mS for a telegraph speed of 50 bauds), so that undistorted signals are indicated at the centre of each traverse.

The use of a rectilinear beam-sweep entails the provision of means of calibration to ensure that a linear measurement of the horizontal traverse against a fixed scale represents accurately a time interval. This is provided by making the frequency of the time-base controlling oscillator six times that of the time-base itself, so that signal indications which are accurately 0, $+33\frac{1}{3}$ and $-33\frac{1}{3}$ per cent. relative to perfect signals can be used to mark the trace (see Fig. 2). By manipulation of the horizontal shift and gain controls, these markers may be positioned to agree with the corresponding points on the fixed scale.

Measurement of the transmission speed can be easily made, if the transmission is at the maximum character repetition rate, by eliminating the separation of the element traces and the automatic start-stop action, so that the primary time-base runs continuously. The indications of the instants of modulation will move across the screen at a rate proportional to the speed error. This is measured by varying the time-base frequency with a calibrated control to attain synchronism. To ensure the maintenance of accurate measurement, means are provided for checking and

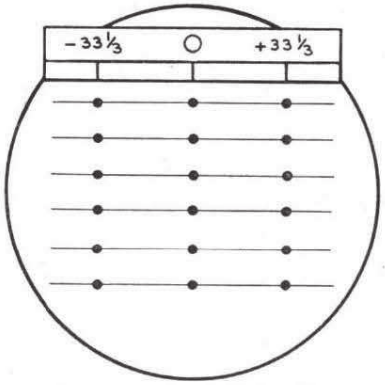


FIG. 2.—CALIBRATION OF SCALE.

adjusting the frequency of the time-base control oscillator against an external standard.

Description of the Instrument.

A T.D.M.S. designed on the foregoing principles is shown in Fig. 3.

The C.R. tube has a 6-in. screen and is provided with a scale of length 4 in., graduated over the range ±40 per cent. distortion. The calibrated control for direct speed measurement has a range of ±1·1 per cent. of the nominal speed. The total

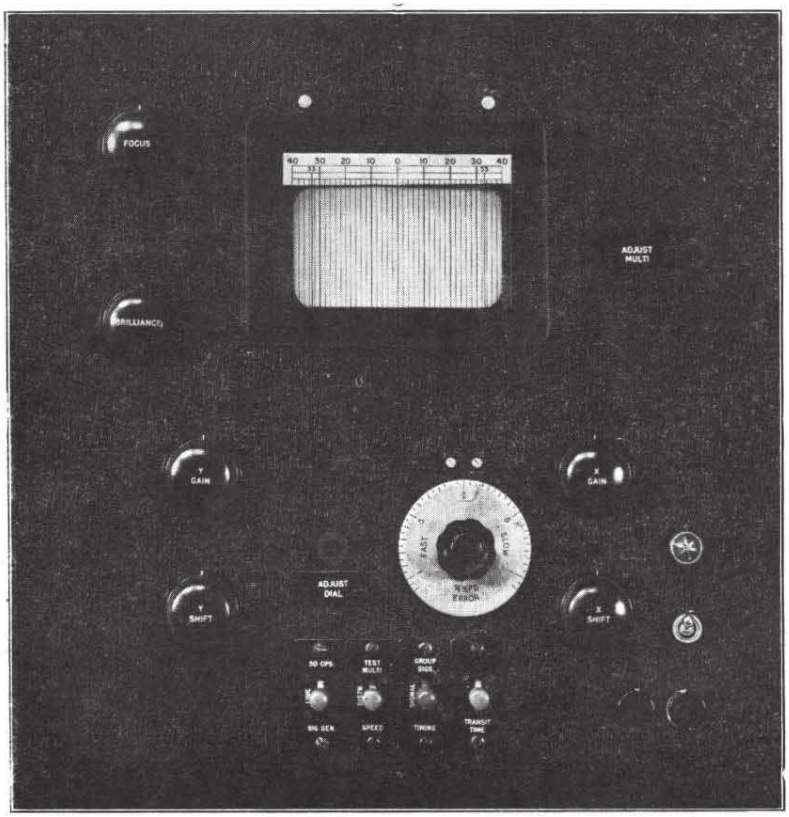


FIG. 3.—FRONT VIEW OF THE T.D.M.S.

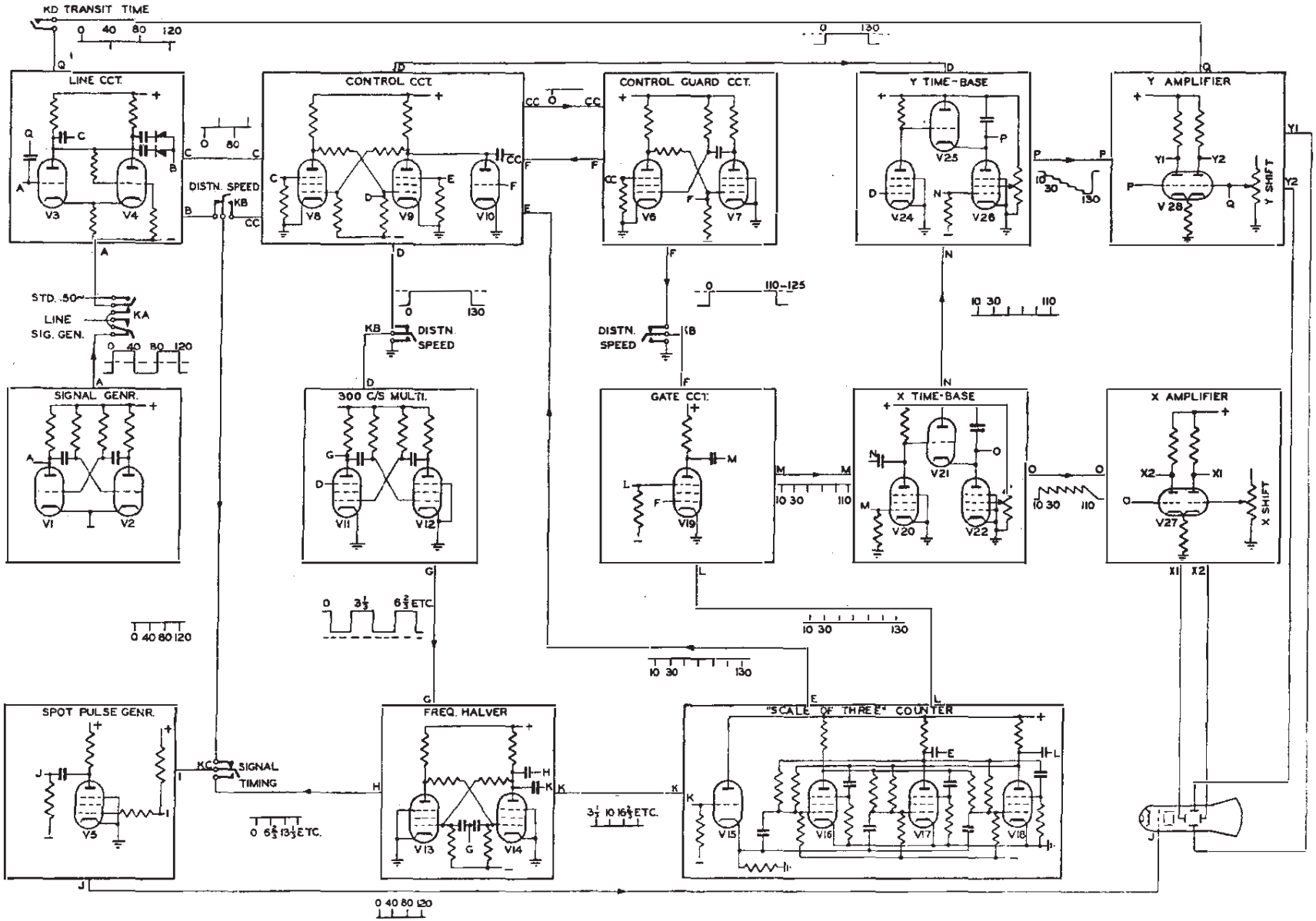


FIG. 4.—SCHEMATIC DIAGRAM OF THE T.D.M.S.

number of valves employed is 34 ; 26 of these are miniature valves which are used in the switching circuits, whilst the deflection amplifiers and power rectifiers are normal-sized valves.

The overall dimensions are $14\frac{1}{2} \times 14\frac{1}{2} \times 18\frac{1}{2}$ in., the weight is 60 lb. and the power consumption 140 watts from A.C. mains.

Outline of Circuit Operation.

The operation of the switching circuits of the electronic T.D.M.S. may be followed by reference to the simplified schematic diagram shown in Fig. 4. The voltage waveforms shown in this diagram are those which exist when the instrument is employed for the measurement of distortion, the input signal being derived either from the local signal generator (V1, V2) or from a teleprinter generating the letter I, depending upon the setting of key KA. The signal generator is for use as a source of signals to assist in setting up the instrument when there are no line signals available, and is a continuously running multivibrator with a relaxation time of 40 mS. It therefore gives reversals at t=0, 40, 80 and 120 mS, simulating the continuous transmission of the letter I in the teleprinter code. The line circuit, which is a Schmitt trigger, acts as a signal shaper and generates a steep-fronted reproduction of the input signal waveform. Differentiation of the waveform at the anode of V3 produces negative impulses at each mark-to-space transition and positive impulses at each space-to-mark transition. Impulses at the same instants, but of the reverse polarity, are produced at the anode of V4. The impulses from V3 are applied over path C to the control circuit. This circuit, a two-position trigger, is operated by the impulse at t=0 and generates a negative impulse at CC, which actuates the control guard circuit, a pulse trigger with a predetermined period of between 110 and 125 mS. The operated control guard circuit holds the control circuit in its operated condition and also opens the gate circuit, when key KB is set at DISTORTION, over connections F.

The operation of the control circuit permits the 300 c/s multivibrator V11, V12, which is the time-base controlling oscillator, to commence oscillating by applying a positive potential to the latter over path D, when key KB is set at DISTORTION. This multivibrator drives the frequency halver over path G, the negative driving impulses occurring at the instants t = 0, $3\frac{1}{3}$, $6\frac{2}{3}$ mS, etc. Positive impulses are derived from the frequency halver to drive the scale-of-three counter at t = $3\frac{1}{3}$, 10, $16\frac{2}{3}$ mS, etc. over path K and negative impulses at t = 0, $6\frac{2}{3}$, $13\frac{1}{3}$ mS, etc., are taken over path H to the spot pulse generator with the key KC set at TIMING (when calibrating the scale). The scale-of-three counter is stepped on by impulses every $6\frac{2}{3}$ mS, commencing at t = $3\frac{1}{3}$ mS, and produces negative impulses at t = 10, 30, 50 mS, etc., which are applied to the control circuit over path E. The first six of these impulses are ineffective in restoring the control circuit because it is, as already described, biased by the control guard circuit for a period of between 110 and 125 mS from the commencement of the start signal. The seventh resetting impulse, at t = 130 mS, is effective and the control circuit is restored at this instant. The control circuit therefore remains operated for a period of exactly 130 mS from the commencement of the start signal, after which it restores and prevents further operation of the multivibrator, frequency halver and scale-of-three counter.

The scale-of-three circuit also generates positive impulses which are fed to the gate circuit over path L. The gate circuit is kept open by the control guard circuit over path F for a period of 110-125 mS, and therefore permits the passage of the first six of the impulses from the scale-of-three counter, but rejects the seventh impulse, at t = 130 mS. Therefore, the output of the gate circuit consists of six negative impulses at t = 10, 30, 50 mS, etc., which are transmitted over path M to the X time-base generator. The X time-base circuit generates a linear saw-tooth waveform by charging a capacitor from a constant current source, i.e. the pentode V22. The capacitor is discharged and allowed to recommence charging at the instants t = 10, 30 mS, etc. The charging rate can be controlled by varying the screen potential of the valve, thus controlling the input to the X amplifier and therefore the amplitude of the horizontal deflections of the C.R.T. The output of the X time-base generator is applied to the X amplifier over path O, and thence to the horizontal deflector plates of the C.R.T. From the waveform shown, it is clear that there will be six horizontal traces on the screen of the tube, the spot moving off the screen towards the right on the completion of the last trace.

The X time-base circuit also generates six positive impulses at t = 10, 30 mS, etc., which are fed to operate the Y time-base circuit. This circuit generates a stepped voltage waveform which is applied over path P to the Y amplifier and thence to the vertical deflector plates of the C.R.T. The waveform which is shown at point P is produced by the intermittent charging of a capacitor in the anode circuit of the valve V26 at the instants t = 10, 30 mS, etc. The magnitude of the charging current, and therefore of the voltage steps, is adjusted by means of the potentiometer in the screen circuit of V26. The capacitor is discharged by the action of the control circuit at t = 130 mS over path D, thus causing the spot to move vertically off the screen of the tube at this instant.

The combined effect of the X and Y deflecting voltages is to cause the spot to make six horizontal sweeps across the screen of the C.R.T., there being a vertical displacement between each sweep. These sweeps commence at the instants t = 10, 30, 50 mS, etc., the duration of each sweep being 20 mS. Normally, the BRILLIANCE control is adjusted so that the traces are not visible when making measurements of distortion.

The X and Y time-base amplifier circuits, which are basically identical, are cathode-coupled push-pull amplifiers and give symmetrical deflection voltages to the plates of the C.R.T.

Production of Displays on the C.R.T. Screen.

With KC set at TIMING, and signals being received from line or the internal signal generator, calibrating impulses derived from the frequency halver at H will

be applied to the spot pulse generator with the result that the trace on the C.R.T. screen will be brightened at instants $13\frac{1}{3}$, 20, $26\frac{2}{3}$ mS, etc., after the commencement of the start element. The X gain and shift controls are then adjusted so that the spots coincide with the $-33\frac{1}{3}$, 0 and $+33\frac{1}{3}$ per cent. scale graduations.

With the key KC set at SIGNAL, the spot pulse generator is connected to B of the line circuit, at which are produced negative impulses at each instant of modulation of the received signal, these impulses being derived by rectification of the differentiated waveforms occurring at the anodes of V3, V4. Taking as example the character I, the spot pulse generator applies positive impulses to the modulator grid of the C.R.T. over path J at the nominal instants of 0, 40, 80, 120 mS. These produce on the second, fourth and sixth traces bright spots, which will be displaced from the centre to the left or right, according to whether they occur before or after their nominal times. The amount of displacement, or distortion, can then be read from the graduated scale as a percentage of the unit element period.

With key KD operated to TRANSIT TIME, the change of potential occurring at the point A in the line circuit, when the transmitting contact commences its transit, is passed over path Q to the Y amplifier to cause a small vertical deflection of the trace at this instant, which may be viewed by increasing the brilliance of the trace (see Fig. 5). The horizontal displacement

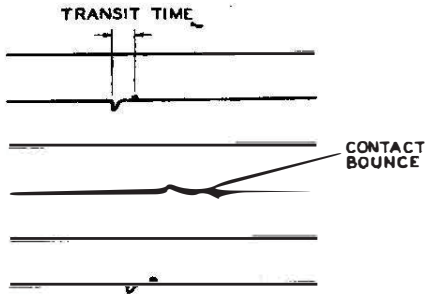


FIG. 5.—C.R.T. DISPLAY SHOWING TRANSIT TIME.

between a deflection and the bright spot on the same trace, which occurs when the contact has completed its transit, is a measure of the duration of the transit time of the contact. Additional deflections subsequent to the spot indicate the occurrence of contact bounce.

The duration of the transit and of contact bounce is easily resolved from the distortion scale, as 5 per cent. corresponds with a time interval of 1 mS.

Measurement of Teleprinter Speed.

When key KB is set at SPEED, the multivibrator is disconnected from the control circuit and runs continuously. The gate circuit is disconnected from the control guard circuit and held open. Thus, the X time-base is permitted to run continuously. Another contact of key KB (not shown) is employed to disconnect the input to the Y amplifier, so that there is no vertical displacement between sweeps. The input of the spot pulse generator is disconnected from the line circuit and connected to the control circuit so that it receives a single negative impulse at the commencement of each character. With $7\frac{1}{2}$-unit characters, two spots will now be observed on the screen of the C.R.T., these spots moving across the screen towards the left or right according as the machine speed is fast or slow. The frequency of the multivibrator is now adjusted until the spots become stationary and the percentage speed error of the machine read directly from a graduated dial, which has a range of $\pm 1{\cdot}1$ per. cent. speed error. (To simplify the diagram, the arrangement for varying the frequency of the multivibrator has not been shown. When key KB is operated, the fixed timing resistors are replaced by variable ones to permit adjustment of the frequency).

Conclusion.

The introduction of this instrument into service should greatly facilitate the accurate measurement of distortion in teleprinter systems, and enable measurements to be made during the actual operation of circuits, a process which hitherto has proved to be difficult.

The authors would like to acknowledge the assistance given by other members of the Telegraph Group of the Research Branch in the development of this instrument.

Book Review

" Fractional Horse Power Motors." C. G. Veinott. McGraw-Hill Publishing Co., Ltd., London. 538 pp. 383 ill. 30s.

The author has taken the opportunity of a second edition to re-write portions of the book and to rearrange the subject-matter dealing particularly with maintenance and the application of fractional horse-power motors. Small electric motors have innumerable uses both in domestic and industrial appliances and this book is a comprehensive survey of present-day practice in the U.S.A. in this field. The fact that it is U.S.A. manufacturers' products which are dealt with is brought out in the first chapter, in which the " Story behind the nameplate " is told, and code letters for various manufacturers are given. The definition of horse-power rating and of fractional horse-power motors are not those in general use in Great Britain. The greater portion of the book is devoted to A.C. motors, but the treatment of small D.C. and universal motors is adequate.

The purpose of the book is to present comprehensive information which will be of value to practical men dealing with maintenance and repair problems and also to those designers who have to incorporate small motors in machines of one sort or another. This purpose has been fulfilled in a very well-produced and illustrated publication. It can be recommended as being authoritative on U.S.A. practice, but the reader should bear in mind that the descriptions given do not necessarily apply to products of British manufacturers.

W. T. G.

Television Radio-Relay Links*

A. H. MUMFORD, O.B.E., B.Sc.(Eng.), M.I.E.E., and Capt. C. F. BOOTH, O.B.E., M.I.E.E.

U.D.C. 621.397.743

Considerable interest has been aroused by the opening of the radio-relay link between London and Birmingham, which is now in everyday use for the exchange of television programme material. The article, having first outlined the transmission characteristics required of long-distance relay links, discusses the radio transmission of video signals, refers to an experimental system in use between London and Cardiff, and then describes, in some detail, the London-Birmingham radio-relay system.

Introduction.

THE need for an effective network for the relaying of video signals between London and various provincial centres is even more important to the growth of our television service than the corresponding sound network has been to the evolution of sound broadcasting. The reason for this is twofold. Firstly, the costs of "live" studio television broadcasts are very many times greater than for sound broadcasts. Secondly, the range of television stations for a high-grade service is generally considered as limited to about 50 miles, due to the "quasi-optical" propagation of the high radio frequencies necessarily used for the purpose. Thus, to ensure a nation-wide television service, several widely-separated stations are required and, because of the prohibitive costs of live programmes, it is not practicable at present to consider the origination of live studio programmes simultaneously at all the stations.

Two methods of relaying video signals over long distances are practicable at present, the one using coaxial cable and the other radio. In the distant future, long-distance transmission by wave guide may become practicable. The comparative merits of cable and radio systems are being studied in many countries and the Post Office has embarked on a large-scale experiment between London and Birmingham in which radio and cable systems will be compared and their performances assessed. However, it is not proposed in this article to consider both radio and cable systems. Attention will be confined to an examination of the problems involved in the transmission by radio of the video signals employed in the 405-line television system now standardised in the United Kingdom and of the provision of two actual radio systems. One of these is an experimental system which has been set up by the Post Office Radio Development Branch between London and Castleton, near Cardiff. Its purpose is to provide experience of television relaying, and in particular of a relatively simple type of system. The second system connects London and Birmingham and is carrying the video programme for the recently opened B.B.C. station at Sutton Coldfield. This link has been designed and installed by the General Electric Company to a performance specification issued by the Post Office. Both links have been engineered to carry 405-line signals, but their designs differ appreciably because of the very different carrier frequencies employed, some 200 and 900 Mc/s for the Post Office and General Electric Company systems, respectively.

It is of interest to note the development and application of radio relay systems in the United States of America. A system [1,2,3,4] carrying two video channels between New York and Boston has been operating since 1948. The 220-mile system is divided into eight links, varying from 11 to 35 miles long. A larger project is the 900-mile system (35 links) joining New York and Chicago, which is now being installed. It is likely eventually that the New York-Chicago system will be extended to San Francisco to give a coast-to-coast system, 2,500 miles long and including some 70 intermediate relay stations.

However, despite the rapid development of broadband radio relaying systems, it must be stressed that relatively little actual experience is available, in particular of a system containing several links in tandem, and that only as a result of experience over a fairly long period will that necessary fund of operational experience become available to the designer and to the maintenance engineer.

For the sake of completeness it should be recorded that early in 1939 the Post Office placed a contract with E.M.I., Ltd., for an experiment in the relaying of television signals to Birmingham. In this case, the radio signals from Alexandra Palace were to be received at Dunstable and transmitted over a radio link to Sharmans Hill, Charwelton, some 40 miles distant towards Birmingham; thus carrying the signals two-thirds of the way from London to Birmingham. Unfortunately, the war intervened and this early experiment in the radio relaying of television signals necessarily had to be abandoned.

The U.K. Television Standard.

The present standard,[5] which will be employed for many years in this country is detailed briefly below and the waveform is shown in Fig. 1.

Number of lines	405 (202·5 + 202·5 interlaced).
Number of frames	50 per second.
Number of pictures	25 per second.
Line frequency	10,125 c/s.
Modulation	positive (amplitude).

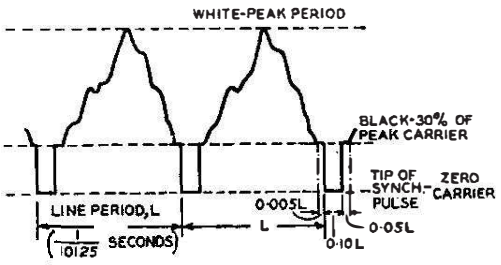


FIG. 1.—405-LINE SIGNALS, U.K. TELEVISION STANDARD TYPICAL LINE SIGNALS DURING FRAMES.

* This article is based on a Paper read by the authors before the Institution of Post Office Electrical Engineers.

[1]For references see Bibliography.

The signal carries two sets of intelligence, the pulse synchronising signals which ensure the exact synchronism of the electron beam in the cathode-ray tube at the receiver with the corresponding beam in the television camera at the transmitter, and amplitude-modulated signals conveying the picture detail, the demodulated signals being arranged to control the intensity of the electron beam of the cathode-ray tube at the receiver and hence to build up the transmitted picture with the help of the synchronising signals.

Specification of Transmission Characteristics

The specification must be such as to ensure that there is no perceptible degradation of the picture after transmission over the longest distances which may be employed. This definition is a subjective one and its translation into a technical specification is a difficult matter, particularly since the subjective and objective assessments vary for different types of picture and between observers. However, the subjective characteristics must be translated into minimum acceptable electrical requirements which are capable of objective measurement and precise specification. The analysis made in the following paragraphs of this section is based broadly on the specification of the London-Birmingham system, but while it covers the main points it is not complete and is only intended to give a very general survey of what is necessarily a most complex specification. In deriving the limits for a single system it has been assumed that several such systems may be connected in tandem.

As already indicated, actual experience of long-distance television relay systems is not very extensive. In consequence, it is not certain that a correct balance has been struck between the specified electrical characteristics and their subjective result, and, as further knowledge and experience are obtained, modification of such specifications may be necessary.

Frequency Band of Video Signals.

The frequency band necessary for the effective transmission of a video signal can be determined from a consideration of a picture of black and white squares in which it is assumed that the squares are the smallest elements to be resolved, and that equal horizontal and vertical definition is required. The minimum value of the highest frequency in c/s for the effective transmission of such a picture is equal to half the number of elemental squares scanned per second, and a system with a pass band up to this frequency is satisfactory. Thus, the effective frequency band is a function of the square of the number of lines, the height-to-width ratio of the picture and of the number of pictures transmitted per second. For 405-line signals, assuming equal horizontal and vertical definition, the bandwidth requirement is some 2,800 kc/s, and for effective transmission, frequencies up to this value must be transmitted without serious loss.

The permissible variation in loss within this band is set by considerations of the smallest perceptible brightness changes that are visible in picture areas adjacent to sudden transitions. For example, departures from a flat characteristic at the lower frequencies will cause black-to-white or white-to-black transitions to be followed by long streaks, while if the departures occur at higher frequencies the streaks become correspondingly shorter. This calls for a substantially flat attenuation/frequency characteristic free from marked changes of level from about 20 c/s to 3,000 kc/s. Over this range the maximum permissible departure from flatness is at the highest frequency where it should not exceed about 1 db. Frequencies below some 20 c/s may be attenuated in part of the circuit provided that they are finally reconstituted in a restoring circuit; this can be accomplished by restoring the bases of the synchronising pulses, i.e., the black level of the picture signal (Fig. 1), to a constant level. The sharpness of the cut-off above 3,000 kc/s is limited by phase linearity requirements, and for this reason a slow cut-off above 3,000 kc/s is usual. If too sharp a cut-off is used the equalisation of the phase/frequency characteristic becomes difficult.

The attenuation and phase characteristics are, of course, mutually dependent and must, in fact, be considered together, particularly in respect of waveform response at low frequency. It is necessary for the phase/frequency characteristic to be substantially linear from 20 c/s to 3,000 kc/s and to pass through zero when extended back to zero frequency. The maximum departures from overall linearity being about 2° between 20 c/s and 500 kc/s and increasing uniformly from 2° to 8° over the frequency range 500 to 3,000 kc/s.

Transient Response and Non-linear Distortion.

The build-up time, defined as the time taken for the response to a suddenly applied signal to increase from 10 to 90 per cent. of the ideal amplitude, may not exceed 0·2 micro-seconds. The permissible maximum value of overshoot, the amount by which the maximum instantaneous response to a suddenly applied input may exceed the steady-state response, may not exceed 2 per cent. The figures for permissible build-up time and overshoot implicitly set limits to the rate at which the response of the system may fall at above 3,000 kc/s, and the extent to which the phase characteristic departs from linearity in this region.

Considering now the limits of non-linear distortion over the range of levels occupied by the complete signal, i.e., from the tip of the synchronising pulses to peak white, the slope of the curve relating signal level at the output to that at the input of the system should be within the limits of 0·9 to 1·1 relative to the slope of an ideal linear characteristic.

Signal-to-Noise Ratio and Echo Distortion.

The presence of noise[6] on the video signal shows up as a brilliance modulation on the picture and the permissible amount of noise is dependent on the type of picture and on the regularity and type of the noise.

Random noise gives a non-pattern type of interference over the complete picture, and its effect is perhaps the least objectionable of all types of noise. Impulsive noise as produced by ignition systems of motor cars gives bright spots of light on the picture. These can be very disturbing

to the viewer. Noise caused by interference from other radio signals normally gives a pattern type of interference and can be very troublesome. In considering the permissible values of the several types of noise, both signal and noise will be specified in terms of their peak-to-peak values (D.A.P. values). The D.A.P. signal level is defined as the magnitude of the vision signal voltage lying between black and white, synchronising pulses being excluded. The ratio at the output of the system of the D.A.P. signal level to the D.A.P. level of noise must be not less than 50 db.

The overall gain stability, in terms of output vision signal level relative to input vision signal level, is required to be better than 0·3 db. at a reference video frequency of 10 kc/s, the quoted limit being maintained without readjustment.

The ratio of the D.A.P. signal level to the D.A.P. level of a permanent type of echo signal which is delayed by more than 0·25 micro-seconds must not be less than 40 db.

Radio Transmission of Video Signals

Selection of Carrier Frequency.

Perhaps the most important single problem in the engineering of a radio-relay system for television signals is the selection of the carrier frequency to be used. The wide frequency band required for a television system and the urgent needs of other services for frequencies below about 150 Mc/s set this as a lower limit for the carrier frequency of a radio-relay system. The higher limit of some 10,000 Mc/s is set by the absorption of wave energy by water vapour, snow, sleet, hail and rain, and by general fading. Thus, the frequency range which can be considered at the present time is about 150 to 10,000 Mc/s. There are, of course, many other factors which influence the selection of carrier frequency, including propagation, aerial efficiency, valve efficiency and availability, and these factors will now be briefly discussed. It is not proposed to consider the general question of international and national frequency allocation as it is outside the scope of the article, but naturally these allocations do prescribe the frequencies which may be employed.

Considering first the propagation of radio waves in the quoted range, effective transmission is only by the direct wave, ionospheric reflection not being experienced, and so the transmissions are limited to line of sight. The signal-to-noise ratio, neglecting man-made, precipitation and solar noise, for the free-space propagation of electric waves between points separated by an optical path, is proportional to

$$\frac{W_T G_T G_R}{N f^2 d^2}$$

in which d is the path length.

f is the carrier frequency.

N is the noise factor of the receiver, i.e., the ratio of the signal-to-noise ratio obtained from the receiver to the signal-to-noise ratio of an idealised receiver free from valve noise.

W_T is the transmitted power.

G_T is the power gain of the transmitter aerial with reference to that of a half-wave dipole.

G_R is the power gain of the receiver aerial with reference to that of a half-wave dipole.

In some practical cases the received signal is the resultant of both the free-space wave and a wave reflected at the mid-path as shown in Fig. 2 (*a*). For

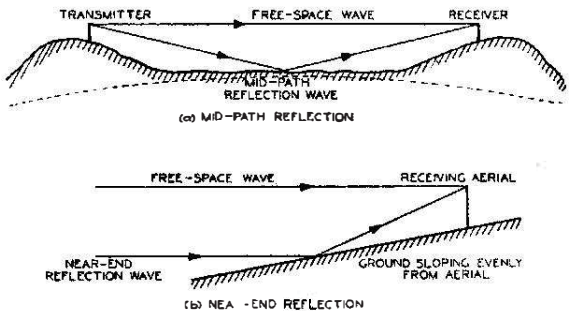


Fig. 2.—Propagation of Free-space and Reflected Waves.

the frequency range under consideration and assuming small angles of elevation at the mid-path reflection, the reflection coefficient can approximate to unity with a phase change of 180°. The power gain due to the reception of the two waves is dependent on the effectiveness of the reflection and on the difference in path length of the direct and reflected waves, and although a theoretical power gain of four is possible, in practice the gain is usually less than two. Similarly, power gains up to four, relative to free-space transmission, can be realised theoretically at both transmitting and receiving terminals by exploiting reflections immediately in front of the respective aerials as detailed in Fig. 2 (*b*). Here again, however, a more practicable figure is one to two. The efficiency of both mid-path and terminal reflections decreases as the frequency of operation is raised since scattering rather than reflection occurs. In addition, at the higher frequencies, the pronounced directivity of the aerial rejects the locally reflected signals. Nevertheless, it is apparent that, in addition to the provision of aerials sufficiently high above the surrounding terrain to ensure opticality between aerials, it is generally advantageous to adjust the aerial height for optimum signal.

Turning to the question of fading, tests have shown that whereas little fading is experienced on optical links working at the lower end of the frequency band under review, some fading does occur at frequencies above about 1,000 Mc/s which can become very serious on occasion at frequencies approaching 10,000 Mc/s. Also, at the higher frequencies absorption by water vapour, snow, sleet, hail and rain can be very serious. Although, as already stated, there is negligible reflection from the ionosphere of the signals in the frequency band under review, anomalous propagation conditions are sometimes experienced through refraction or reflection on account of irregularities in the refractive index of the atmosphere. At

the higher frequencies the signals may be trapped in a narrow layer of the atmosphere which, acting as a waveguide, transmits the signals over long distances. Anomalous propagation over hundreds, even thousands, of miles has been observed, mainly in tropical areas. Considering radio noise, a general reduction of man-made noise can be expected in the future as the effective suppression of the more noisy electrical devices is achieved. The effect of solar noise can be minimised by the use of very directive aerials. Thus, with reasonable precautions, the planning of systems can be made in terms only of receiver valve and thermal noise.

Turning to aerials, since units large in comparison with one wave-length are practicable (the frequency band 150 to 10,000 Mc/s represents a wave band of 2 metres to 3 cm.), highly directional aerials are available. One common form of directional aerial employs a parabolic reflector to focus the radio waves. It can be shown that for a given size of aerial the power gain increases as the square of the frequency and the beam width varies inversely as the first power of the frequency. Taking a specific example in which the frequency is 3,000 Mc/s (λ, 10 cm.) and the area of the aerial aperture is 9 sq.m., the aerial gain is some 34 db. above that of a half-wave dipole and the beam width is about 3°. If the same reflector is used at 10,000 Mc/s (λ, 3 cm.) the power gain increases to 44 db. and the beam width reduces to 1°. While such a narrow beam width is helpful in restricting trouble due to echo signals and in minimising noise pick-up, it is liable to lead to difficulty in aerial alignment and to occasional loss of gain due to small changes of wave direction caused by variation of atmospheric refractive index. Changes due to this cause of 0·5° are actually experienced. It will be realised from what has been said that a practical upper limit is set to the gain on a link from aerial directivity.

Perhaps the most practical factor influencing choice of frequency is the valve development position. In general, while more or less standard types of valves are satisfactory for frequencies up to a few hundred Mc/s, an upper frequency limit is set by transit-time effect due to the inter-electrode spacing; the less the spacing the higher the upper limit of frequency. Considerable advances have been achieved in this direction, and in the U.S.A. a " close-spaced " triode[7] has been developed which is capable of operation up to some 4,000 Mc/s. It is of interest to note that the grid-cathode spacing of this valve is only 0·0006 in. with a grid-anode spacing of 0·01 in. As a Class A amplifier, it will give a gain up to 10 db. with a bandwidth exceeding 100 Mc/s. No information is available on the valve life and practicability of large-scale production. For frequencies exceeding some 4,000 Mc/s and wide bandwidths it appears that a new type of valve operating on a velocity-modulation principle will be used. This type is known as the travelling-wave valve, and, while very rapid developments have been made, completely satisfactory valves are not yet in large-scale production. Thus, it will be seen that the systems engineer is at present awaiting the provision of completely satisfactory valves before he can utilise fully the possibilities of the higher frequencies. Whatever the type of valve it is generally true that inherent valve noise, and hence the noise factor of the receiver, increases as the frequency is raised and that the valve efficiency and the radio frequency power output of the transmitter decrease.

Considering now the best actual frequencies of operation of a relay system, it has been stated that the signal-to-noise ratio of a link is inversely proportional to the square of the frequency and directly proportional to the gain product of the two aerials, while the gain of an aerial of constant area is proportional to the square of the frequency. Thus, for aerials of a given size, the signal-to-noise ratio of a link is proportional to the square of the frequency. It wouldseem, therefore, that the higher the frequency the better the signal-to-noise ratio, but the several other factors already detailed must be considered; thus, fading increases with frequency and full advantage cannot be taken of the narrower beam width of aerials operating at the higher frequencies, absorption occurs at very high frequencies and valve noise increases with frequency while efficiency and radio frequency output both decrease. It will be appreciated from this that there are sound arguments for using frequency allocations in the lower part of the band, 150 to 10,000 Mc/s, for radio-relay systems. In fact, the two U.K. systems utilise frequencies of about 200 and 900 Mc/s, while the U.S.A. systems which have been briefly referred to employ frequencies of about 4,000 Mc/s. It must be envisaged that as the frequency allocations for radio-relay systems in the lower part of the range, 150 to 10,000 Mc/s, are taken up it will be necessary to take up the higher frequency allocations. Before this can be done, however, there is an urgent need for the development engineer to obtain field experience at these higher frequencies, for which purpose he will require reliable and efficient valves.

Type of Modulation.

The design of a system is simplified considerably if frequency modulation (F.M.) instead of amplitude modulation (A.M.) is employed. Thus, the F.M. signal is not liable to non-linear distortion due to the curvature of valve characteristics, amplitude variations of the signal field at the receiver are removed effectively by the limiter when the minimum incident field is sufficient to ensure full limiter operation and the transmitter design is facilitated by the constant loading of the F.M. system. Finally, even if the frequency swing of the F.M. transmitter is restricted to that of the maximum modulation frequency, a deviation ratio of one, the system gives an effective improvement of about 10 db. over an A.M. system with the same peak power. Possible disadvantages of F.M. operation are the increased bandwidth required and the greater susceptibility of F.M. systems to the effects of echo signals. However, on balance, the F.M. system is to be preferred, as is exemplified by the U.K. and U.S.A. systems to which reference has been made.

Operational Requirements.

It is, of course, essential that any radio-relay system carrying commercial traffic shall be designed on the

basis of unattended operation of the intermediate relay stations. A similar consideration also applies to the terminal stations if these are not located at premises holding other equipment for which attended operation is necessary. This proviso emphasises the importance of reliability, which can be achieved only by good design and by the sound engineering of that design. Components, and in particular valves, must be of the long-life type. Reserve equipment which can be instantly switched into circuit from a remote control point if the performance of a working unit deteriorates, must be provided. To meet these requirements an adequate monitoring and supervisory system is essential. This system must not by its complexity introduce additional risks of failure of the link, but it must be able to draw attention at the control point to fault conditions which are likely to impair the operation of the system, and also to change over equipment automatically on the occurrence of a major fault. In short, it should enable an effective control of the system to be maintained at all times.

The ultimate performance of a system under traffic conditions is equally dependent on both the supervisory and traffic circuits; neither can be neglected at the expense of the other, but experience does suggest the very minimum complexity of the former for satisfactory operation.

The London-Castleton Radio-Relay System†

When it was possible early in 1946 to return to a consideration of the radio relaying of television signals, the choice of frequency to be used was much more limited by valves than is the case today. Because of this and of the experience already gained in the design of wideband equipment operating on about 200 Mc/s, consideration was given to setting up an experimental system using frequencies about 200 Mc/s. It was felt that the design of a system including several intermediate relay stations would be considerably simplified by restricting the frequency used to a range at which effective amplification could be achieved without recourse to frequency changing to a lower intermediate frequency. It was, in fact, within the bounds of possibility that a "single frequency" relay system in which each repeater merely acts as a "straight" amplifier, could be developed. The simplicity of such a system as compared with that of a link at which frequency changing is required at each intermediate repeater was fully appreciated, as also was the difficulty of ensuring a sufficiently low level of feedback from transmitter to receiver at an intermediate repeater. Finally, it was decided to set up an experimental "single-frequency" system between London and an existing experimental radio laboratory at Castleton, near Cardiff, to give one-way transmission from London to Castleton, using frequency modulation with a maximum frequency deviation of $\pm$ 3 Mc/s about a mean carrier frequency of 195 Mc/s, the system being designed for the transmission of video signals up to a maximum frequency of 3 Mc/s. Pictures were first sent over the complete system on 24th March, 1949, and since then a considerable amount of experimental data on the relaying of video signals has been accumulated, the tests still being in progress.

† The full description and performance of the link, included in the Paper previously referred to, will be given in the next issue of the Journal.

The London-Birmingham Radio-Relay System

Sutton Coldfield, the second television station in this country, was formally opened on 17th December, 1949, thereby extending the television service to the densely populated area of the Midlands. Since the operation of this station is dependent upon an exchange of television programme material with London, the Post Office was called upon to provide the necessary relaying facilities for this purpose. Accordingly, a detailed specification was issued in November, 1946, for the interconnection of London and Birmingham by a relay chain of low-power, unattended radio stations as one of the means of relaying television signals between London and Birmingham; satisfactory transmission of video frequencies up to at least 3 Mc/s being one of the requirements. Another requirement of this specification called for the system to be so designed that, even if the system were to be extended up to some 400 miles or so, there should be no noticeable impairment of the television signals. Tenders were invited from a number of manufacturers, the contract being awarded to the General Electric Co., Ltd., in May, 1947. The specification calls for the provision of a radio link providing for the simultaneous transmission in both directions of the 405-line television signals between Museum exchange, London, and Telephone House, Birmingham. However, it was foreseen at the time of placing the contract that it might not be possible to provide the full two-way installation in time for the opening of the public television service from Sutton Coldfield, and arrangements were, therefore, made for one of the channels to be completed before commencing the installation of the other and for the direction of transmission of this one channel to be reversed at will in less than ten seconds. The service is now in operation on this reversible basis and has been provided by supplying just over 60 per cent. of the complete radio equipment, using aerial systems erected on temporary masts provided by the Post Office and equipment installed in buildings at the foot of the masts for the intermediate repeater stations. Whilst the remainder of this article will deal mainly with the radio system as operating at present on the single-channel reversible basis, an outline of the supervisory equipment and full two-way scheme will also be given.

General Outline of the System.

Previous mention has been made of an experimental system in which not only do the radio transmissions remain on a single but distinct frequency for each direction of transmission throughout the system, but also one in which each radio repeater station operates as a straight amplifier, without recourse to any lower intermediate frequency in the equipment at the repeater stations for securing the required amplification. In the brief discussion on the system the various advantages and disadvantages of the method adopted were mentioned. In the system which is now

operating between London and Birmingham a rather different solution to the problem of relaying television over long distances has been made ; due, in part, to the use of a higher carrier frequency of some 900 Mc/s. Thus, at each repeater station the signals are first reduced from their incoming frequency of about 900 Mc/s to an intermediate frequency of 34 Mc/s, at which frequency the necessary amplification of the incoming signals is readily effected, and then retransmitted on a frequency differing by 20 Mc/s from the frequency of the incoming signals, thereby reducing considerably the risk of interference between the incoming and outgoing signals at repeater stations. It is important to note that the signals are not demodulated to video frequency, except for monitoring purposes, until the receiving terminal station is reached. By this means, the particular difficulties associated with achieving a high degree of linearity, high order of overall frequency stability and accurate D.C. restoration in modulator and demodulator stages are experienced only at the terminal stations and not at each repeater station. An unusual feature of all the transmitters is the use of a frequency changer at the output stage. Only two radio frequencies are required for each direction of transmission, the transmissions alternating from one to the other frequency in successive links throughout the system ; the process is illustrated schematically in Fig. 3.

The route of the radio-relay system betweeen London and Birmingham is shown in Fig. 4. Although

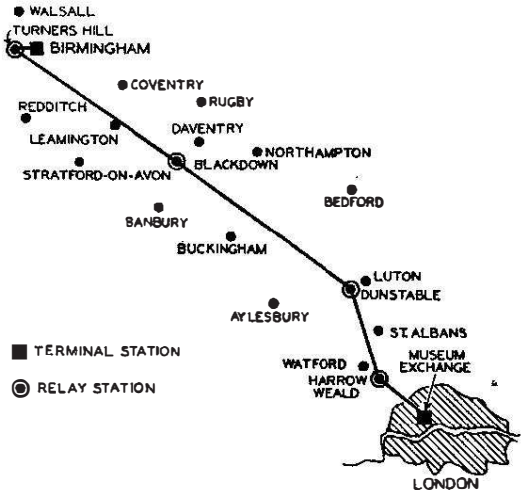


FIG. 4.—ROUTE OF LONDON-BIRMINGHAM TELEVISION LINK.

each station has to be in sight of those on either side of it, only four intermediate repeater stations have had to be provided. Only one site is required at each

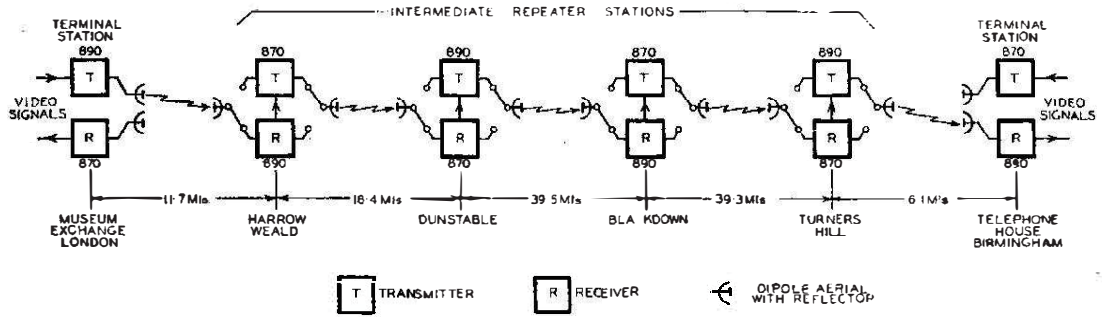


FIG. 3.—SCHEMATIC DIAGRAM OF LONDON-BIRMINGHAM SYSTEM, SHOWING REVERSING SWITCHES SET FOR TRANSMISSION LONDON TO BIRMINGHAM (NUMBERS AGAINST T AND R ARE FREQUENCIES IN MC/S).

Separate but identically similar aerial systems are used for transmission and reception but both aerial systems are mounted at the top of a common mast, some 100 ft. in height. Each aerial system consists of a paraboloid reflector formed from light alloy tubes, having at its focus a coaxial line fed, horizontal dipole with its associated parasitic reflector ; 10 W of radio frequency power being fed into the transmitting dipole. The full diameter of the paraboloid is 14 ft., but its horizontal aperture has been cut to 10 ft. with very little resulting loss of gain. Provision has been made for heating both the dipole head and the tubes forming the reflecting surface of the parabola to prevent the accumulation of ice ; up to 6 kW of heating is required for this purpose. The gain of the aerial is 27·5 db. with reference to that of a half-wave dipole, the beam width in the horizontal plane is $\pm 5{\cdot}5^\circ$ at half amplitude, and the amplitude of the first side-lobe is less than 10 per cent. of that of the main lobe.

repeater station, equipment being installed in buildings at the foot of the single mast used for mounting the aerials (Fig. 5). The sites were, of course, only chosen after an extensive series of trials and in the final choice many factors, other than merely technical factors, had to be taken into consideration, e.g., the preservation of amenities. It will be realised that effective use has been made of natural features, such as the Elstree ridge just north of London, the Chiltern Hills, the Cotswolds, and the high land to the west of Birmingham. The sites have been chosen so that with a maximum aerial height of 175 ft. above ground level, there are clear optical transmission paths between successive stations. This is well illustrated in Fig. 6.

The terminal stations are located in Museum telephone exchange, London, and Telephone House, Birmingham, and, incidentally, the highest aerials are in use at these two stations, the highest parts of these towers being 167 and 196 ft. above street level at

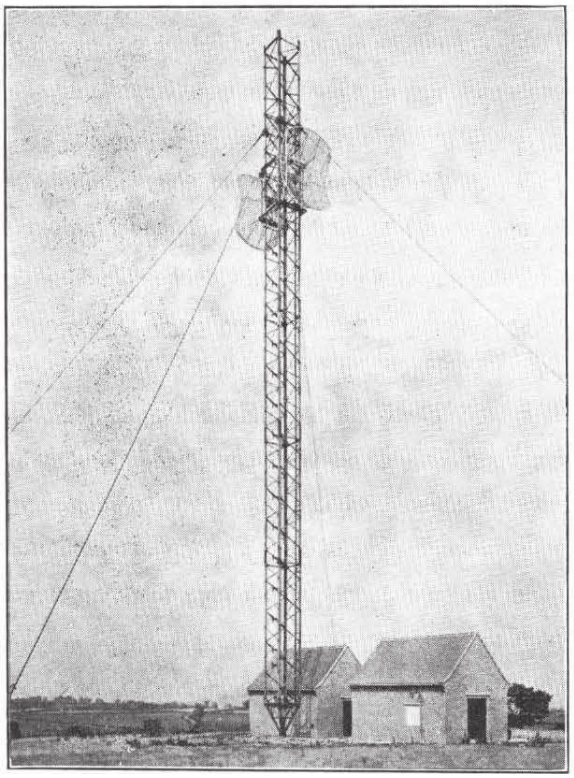


FIG. 5.—THE MAST AND BUILDINGS AT A REPEATER STATION.

used to frequency-modulate an oscillator between 32·5 and 35·5 Mc/s and then this modulated oscillation is amplified and applied, together with the 40-W output of a 900-Mc/s generating chain, to the final stage of the transmitter, which is a frequency changer, the process being outlined in Fig. 8. In this frequency-changer stage, frequencies are produced which differ from that of the radio-frequency generating chain by amounts equal to the frequency of the modulated oscillation. Both these signals, the frequency of one of which is above and the other below that of the radio-frequency generating chain, are frequency-modulated by the vision frequency signal to the same extent as was the original 34-Mc/s oscillator. One of these frequency-modulated sidebands is selected by a filter in the output circuit for transmission, and fed by means of a coaxial feeder to the transmitting aerial; the output power being some 5 to 10 W. The bandwidth of the transmitter frequency-changer and of the transmitter intermediate-frequency amplifier considered together is $\pm$ 4·5 Mc/s at 1·5 db. down.

The F.M. oscillator consists, in principle, of two valves feeding a common anode circuit, flatly tuned to 34 Mc/s, each valve having a feedback path between its grid and the common anode circuit (Fig. 9). The frequency of oscillation is primarily determined by the lengths of the coaxial lines included in the feedback paths. The feedback is applied from the anode through a cathode follower stage, the cathode output of which is connected to the grid circuits of the oscillator valves through a coaxial line so arranged that the electrical length of the coaxial line, at 34 Mc/s,

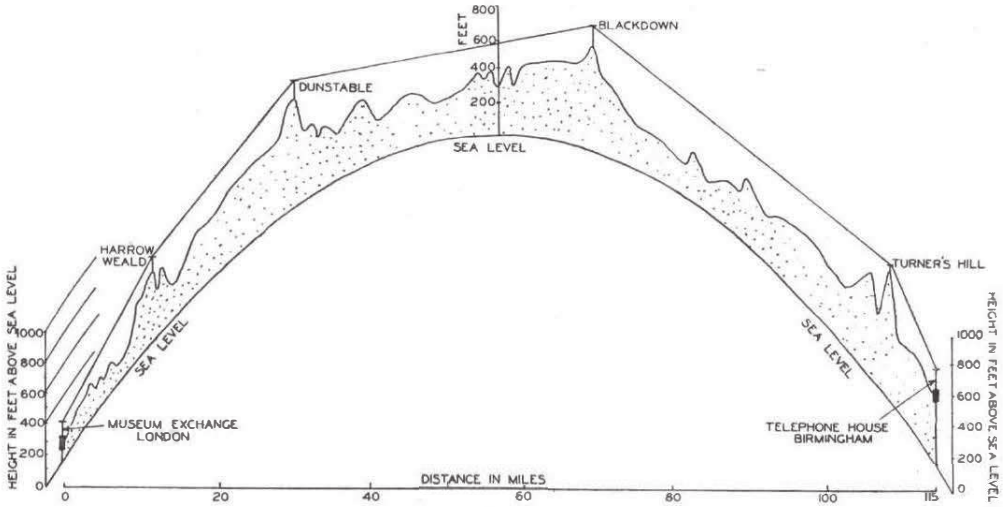


FIG. 6.—PROFILE OF ROUTE LONDON TO BIRMINGHAM (PLOTTED WITH EARTH REPRESENTED AS SECTION OF PARABOLA SO THAT OPTICAL PATHS CAN BE REPRESENTED BY STRAIGHT LINES).

London and Birmingham respectively. The tower at Museum exchange, with its two paraboloid aerial systems, is shown in Fig. 7.

Equipment at the Terminal Stations.

The signals to be relayed are fed from the appropriate centre to the terminal station of the London-Birmingham radio-relay link by means of a coaxial cable,[8] thus providing a video signal for modulating the transmitter. The video frequency signal is first

is $\frac{3}{8}$ wavelength for one valve and $\frac{5}{8}$ wavelength for the other. In the absence of a vision signal, this circuit will oscillate at 34 Mc/s, as the following consideration of the phase relationships shows. An oscillation at 34 Mc/s, applied round the feedback paths, will produce equal inputs in phase quadrature at the grids of the oscillator valves, since the coaxial lines differ in length by $\frac{1}{4}$ wavelength. The outputs from the two oscillator valves will also be of equal magnitude and in quadrature phase relationship,

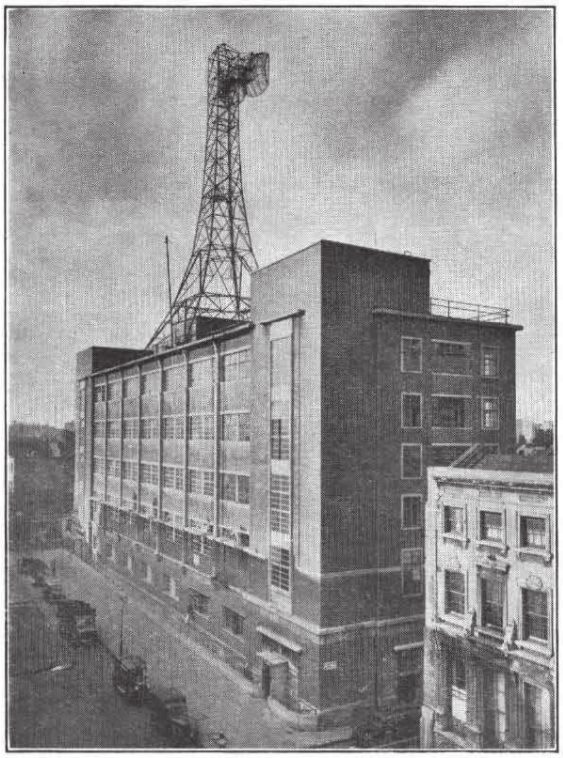


FIG. 7.—THE TOWER AT MUSEUM EXCHANGE, LONDON.

and it will readily be seen, from a consideration of the phase shifts round the feedback path, that the resultant output is in phase with the oscillation

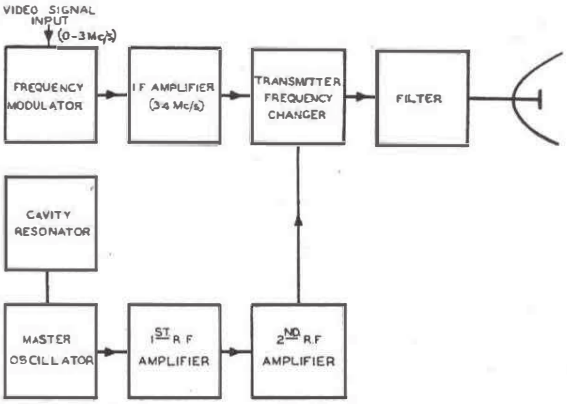


FIG. 8.—BLOCK SCHEMATIC OF TERMINAL TRANSMITTER.

originally postulated ; thus oscillation will be maintained at a frequency of 34 Mc/s. When a vision signal is applied, potentials of opposite polarity are impressed on the grids of the two oscillator valves, so that the output due to one of the valves is increased while that due to the other is reduced. These amplitude changes of the two outputs produce a change of phase in their resultant and oscillation can no longer be maintained at 34 Mc/s. The frequency of the oscillator, therefore, alters, and with it the electrical lengths of the coaxial lines, until, at some new frequency, the phase relationships are again appropriate to maintain oscillation. In this way, the amplitude variations of the vision signal are converted to frequency-modulation of the 34-Mc/s carrier, with

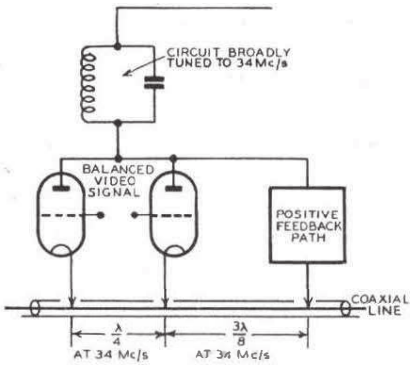


FIG. 9.—SCHEMATIC DIAGRAM OF F.M. OSCILLATOR.

a high degree of linearity. The instantaneous output frequency during the intervals corresponding to the transmission of synchronising pulses is automatically stabilised with reference to a crystal-controlled source.

It will be appreciated that the equipment used in this system necessarily makes use of advanced techniques in valve and circuit design because of the high radio frequency at which it is operating. The radio-frequency equipment is based upon the use of disc-seal triodes and coaxial-line circuits. Each radio-frequency-tuned circuit is essentially a length of coaxial transmission line. The general finish of the radio-frequency circuits is silver plate and a rhodium flash. Air cooling is used in the higher power stages of the transmitter.

The frequency stability throughout the complete system is essentially due to that of the master oscillator at the terminal transmitting station, and since its construction also illustrates the coaxial-line technique, a description of this unit will serve to illustrate the general nature of the design of such high-frequency equipment. A schematic of the circuit arrangement is shown in Fig. **10**. The master

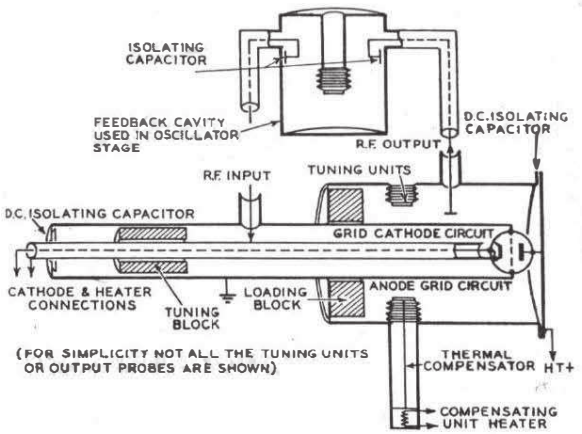


FIG. 10.—MASTER OSCILLATOR (AND 1ST. R.F. AMPLIFIER) SCHEMATIC ARRANGEMENT.

oscillator operates in the 900-Mc/s band, and no frequency multiplication is required in any chain associated with it. The valve used is a disc-seal triode, with a coaxial line connected between the grid and the anode, and another coaxial line connected between the grid and the cathode. The mechanical arrangement is such that these two circuits are themselves coaxial, one of the tubes forming the inner conductor of one circuit and the outer conductor of the other. The anode-grid circuit operates in a three-quarter wavelength mode of resonance with the grid-cathode circuit approximately one and three-quarters of a wavelength long. The heater connection is coaxial with the inner conductor of the grid-cathode line, and is not subjected to any radio-frequency field. Oscillation is maintained by a feedback path, external to the two circuits, which is arranged to include a resonant cavity. Feedback, and therefore oscillation, can only occur at the frequency to which the cavity is tuned. Variations due to temperature changes are minimised by a temperature-sensitive bi-metallic device acting on a bellows tuning unit attached to the outer conductor of the anode-grid circuit. It is of interest to note that the radio-frequency output of the master oscillator is some 4 W, obtained at a D.C. anode efficiency of 22 per cent.

For reception at a terminal station, the received signal is heterodyned by a local oscillator, of the same design as the master oscillator, to give a difference frequency of 34 Mc/s, a silicon crystal being used as frequency-changer. The receiver intermediate-frequency amplifier consists of two stages, each using a pair of low-noise triodes, followed by three automatic gain-controlled stages, each using a pair of pentodes, and two further stages using pairs of pentodes and a cathode-follower output stage. Even if one of the pair of valves used in each stage fails, the amplifier will still continue to work satisfactorily. The action of the automatic gain control is such that a change in intermediate frequency input level of 20 db. is reduced to a change of 0·5 db. in the intermediate-frequency output level. At an intermediate station, this intermediate-frequency output then passes first to higher power intermediate-frequency amplifiers and then to the transmitter-frequency translation stage, as described in the following section, whereas at a terminal station this intermediate-frequency output passes to the terminal demodulators.

The demodulator units include limiters, the discriminator stages and video-frequency amplifiers. Demodulation is achieved by a conventional form of discriminator consisting of two tuned circuits, one tuned above and the other tuned below the intermediate-frequency mid-band frequency. In the interests of stability and linearity, however, conventional lumped circuits are not used but instead, coiled-up sections of coaxial cable are used, end-loaded with small variable capacitors, simulating end-loaded transmission lines. The output vision signal is then passed through amplifiers to the cable-terminated equipment at video frequency.

Fig. 11 is a photograph showing the receivers, waveform and picture monitors and transmitters at the Museum Terminal.

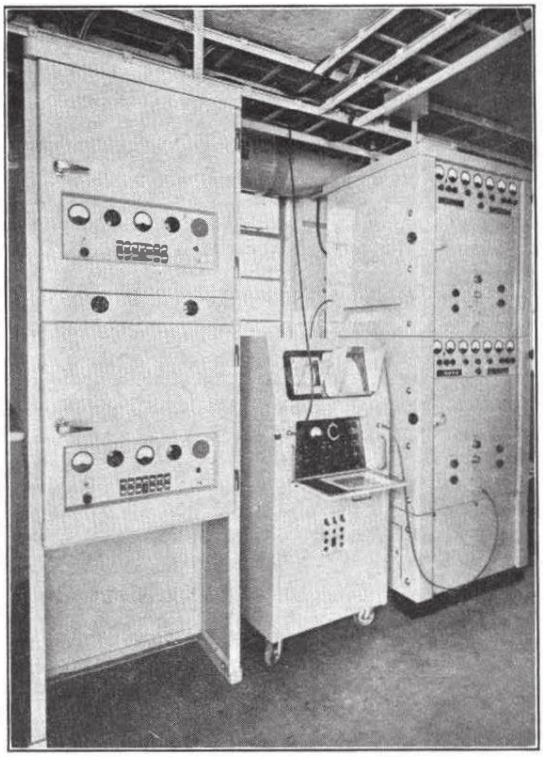


FIG. 11.—RECEIVERS, MONITORS AND TRANSMITTERS AT MUSEUM TERMINAL.

Equipment at the Intermediate Repeater Stations.

A schematic diagram of the arrangement and equipment in use at a repeater station is given in Fig. 12. It has been pointed out that the frequency on which the signals are re-transmitted at an intermediate repeater station is not the same as the received frequency, differing by 20 Mc/s, thereby

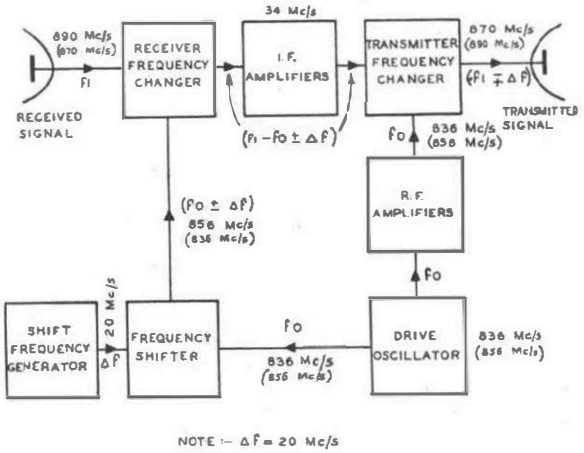


FIG. 12.—ARRANGEMENT OF FREQUENCIES AT A REPEATER STATION (FREQUENCIES IN SMALLER PRINT, IN BRACKETS, ARE ALTERNATIVES).

reducing considerably the risk of receiving power from the local transmitter as well as from the previous station. To achieve the frequency translation, the frequency of the local oscillator of the receiver differs from that of the transmitter drive oscillator. From

the point of view of overall frequency stability, it si convenient to derive the local oscillator frequency from the transmitter drive oscillator. This is accomplished by mixing an output from the drive oscillator with that from a crystal-controlled oscillator whose frequency is equal to the difference between the received and transmitted frequencies, i.e., 20 Mc/s. Thus, the transmitted frequency is made independent of the drift of the station drive oscillator and is affected only by the small drift of the crystal-controlled 20-Mc/s oscillator. Since only two frequencies are used for a channel in either direction, the " shift " frequency is the same at all repeater stations, and is alternately added to or subtracted from the station drive oscillator frequency. By this process, the frequency transmitted from all repeater stations is governed by the received frequency only, subject to the small drift of the 20-Mc/s crystal-controlled oscillators, and the transmitting frequencies throughout a channel are, therefore, effectively controlled by the master oscillator at the transmitting terminal. The design of the drive oscillator is the same as that of the terminal master oscillator.

The actual transmitting and receiving equipments (Fig. **13**) used at the repeater station are basically the same in design as those at the terminal stations, but, of course, the signals being relayed are not demodulated to video frequency until the receiving terminal station is reached. It is of interest to note that the received power for free-space propagation between the parabaloid aerials, over the 40-mile path, is about one microwatt, and since the transmitted power used at each station is some 10 W, the gain required from the equipment (excluding aerials) in such a repeater station is about 70 db.

For the reversible link, now being operated, only two aerials are provided at each repeater station, and since the transmitter and receiver are both connected to each aerial, there is a physical path from transmitter to receiver. The change of direction of transmission is produced by the operation of a contactless switch arrangement which changes the capacitance in a series resonant circuit shunted across a suitable stub connection. As has already been stated, two frequencies only are used, alternately, for the transmitters of the channel. The spacing of these frequencies has been chosen to reduce to a minimum the possibilities of second-channel interference, cross-talk between channels, and the effects of all the possible combinations of unwanted frequencies generated in a repeater station. The arrangement is illustrated in Figs. **3** and **14**.

Miscellaneous Features.

Reliability of service is essential and considerable attention has been paid to this requirement in the design of the equipment and provision of spare facilities. Thus, duplicate signal-channel equipment and power units with changeover switching are provided to maintain the operation of the link in the event of a failure of the working equipment. The equipment, which is not in use, is kept warmed up in a standby condition, so that it is ready for immediate operation. The aerial system and transmitter output filters are not duplicated, and, therefore, a radio-frequency switch has been provided in the output

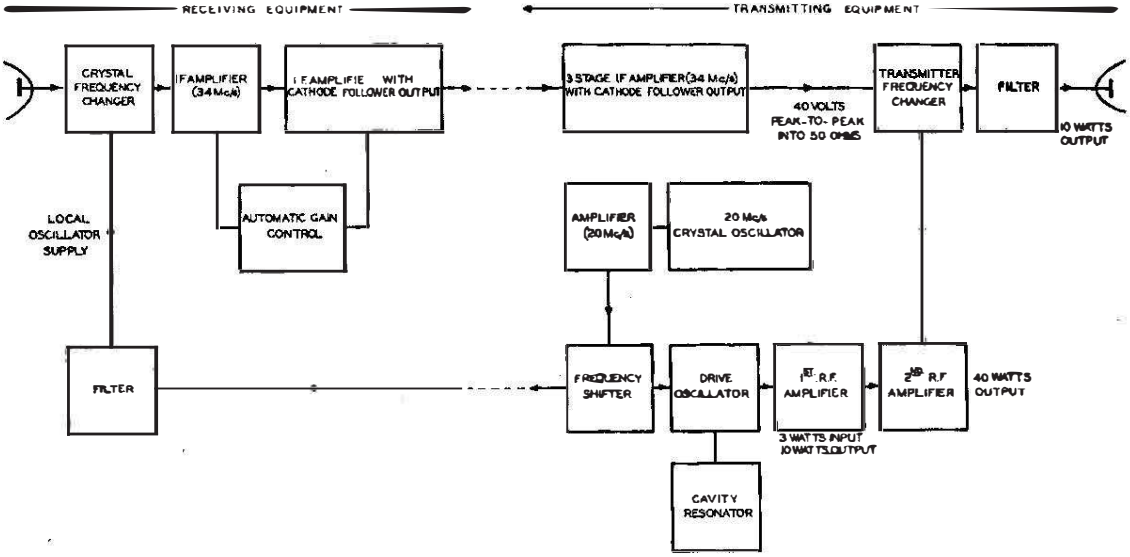


FIG. 13.—BLOCK SCHEMATIC OF REPEATER STATION EQUIPMENT.

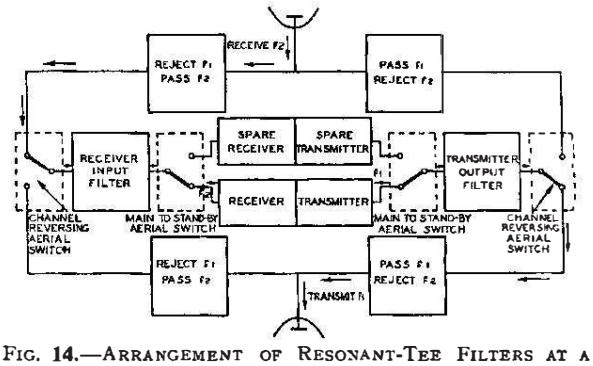


FIG. 14.—ARRANGEMENT OF RESONANT-TEE FILTERS AT A REPEATER STATION TRANSMITTING ON FREQUENCY f_1 AND RECEIVING ON FREQUENCY f_2.

feeder between each main and standby transmitter and the common output filter. Similar switching and filtering is provided at the input of the associated receiver. Changeover switching between the power units and the signal-channel equipment is so arranged that each channel equipment can be connected to either power unit. The power is normally taken from a public supply, but in the event of a mains failure a 15-kW diesel alternator starts up automatically.

Economic provision of radio-relaying facilities can only be made if the equipment can be operated on an unattended basis with only occasional visits from maintenance staff. The radio system can be fully controlled from either control point, i.e., London (Museum exchange) or Birmingham (Telephone House). Fault monitoring is provided on the units of the equipment and the fault indications are transmitted by a voice-frequency signalling system to the appropriate control point over a four-wire line. This signalling system also conveys the control signals from the control point to the radio stations. Only the essential controls are at present in operation, but eventually the fault indications given at the control point for each radio station will include information on whether the station is working, which channel equipment and power unit have been selected, and the occurrence of a fault and consequent automatic changeover in the equipment. Indication will also be given as to whether the mains supply to the station is on and, in the case of a repeater station, whether the standby generator is working. A fault on the supervisory system will also be indicated at the control point. The system differentiates between major and minor faults and only provides for automatic changeover on major faults. The equipment at all stations can be switched on and off from the control point and a changeover made between working and standby units. If the supervisory system fails to switch on the equipment at the various stations, the stations come into operation on pre-set time switching.

Performance of the System.

Since the system, although in daily operation on a reversible basis, has not yet been completed by the contractor and, in fact, even the aerials are not mounted at heights which will be used when the towers become available, it is too early to give full details of the performance. Suffice it to say that there is every indication that when all the equipment for the full two-way system is installed, the system will comply with all the main performance requirements specified and detailed earlier in this article. However, the photographs (Figs. **15** and **16**), which show signals actually transmitted over the system, will give some idea of the present performance.

The Two-way Installation.

The conversion of the system from one-way reversible to full two-way operation is necessarily a gradual process and great care has to be taken to ensure that the reliability of the present service is not impaired in the process. The final repeater station towers are now being erected and in due course all the radio equipment will be installed in special cabins at

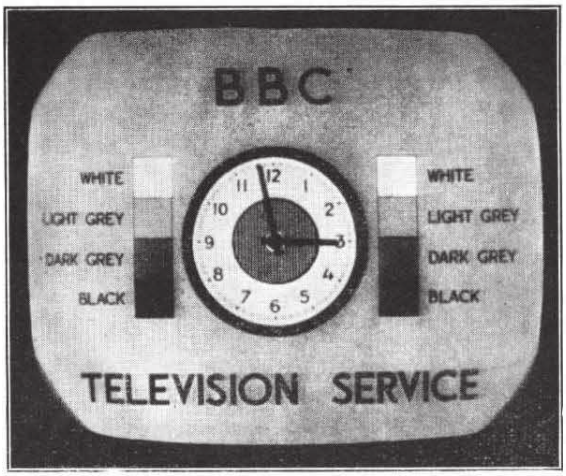


FIG. 15.—TUNING SIGNAL AS RECEIVED AT SUTTON COLDFIELD.

the tops of these towers—see Fig. **17**, which is a photograph of a model of the towers. This will eliminate the losses in the present feeders between the aerial systems and buildings, and avoid any possibility of troublesome echoes from mismatch of the aerial and feeder systems. It is estimated that an improvement of as much as 12 db. in the signal-to-noise ratio will

FIG. 16.—PICTURE OF ANNOUNCER AS RECEIVED OVER THE SYSTEM.

result from these changes. The reversibility feature for the existing channel will not be retained when the system is finally completed. An additional pair of frequencies will be used for the second channel, the general arrangement of the full two-way system being shown in Fig. **18**.

THE FUTURE

It will be appreciated that the long-distance relaying of television signals is still in its early stages and that it is not an easy matter to specify, in the necessary detail, the performance requirements which must be met for the individual systems involved in the relaying over long distances of such signals. Soon,

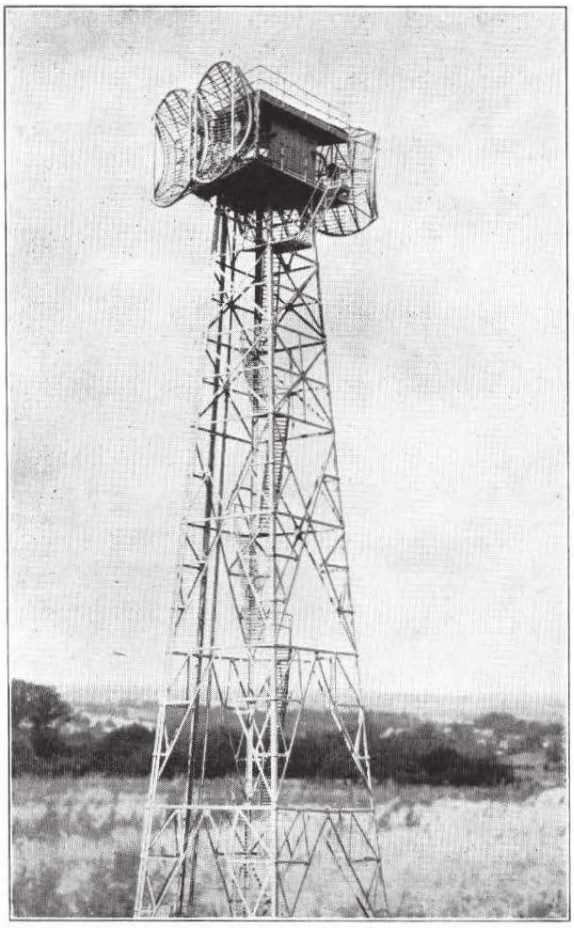


FIG. 17.—MODEL OF REPEATER STATION TOWERS.

practical comparisons of the relaying of television signals by radio and by coaxial cable will become possible in this country, but the results of such comparison cannot be awaited before becoming committed to the actual means of provision for further extensions in view of public demand for the expansion of the television service. Thus, the extension of the television service from Birmingham to the Manchester area will be accomplished by employing coaxial cables ($\frac{3}{8}$ in. diameter) and the extension from Manchester to Edinburgh will be by radio ; thereby commencing the integration of cable and radio-relay systems. Certain it is that with the extension of television to more and more distant places—and some idea of the expansion proposed for this country of the existing 405-line-type signals is given in Fig. 19—the performance required

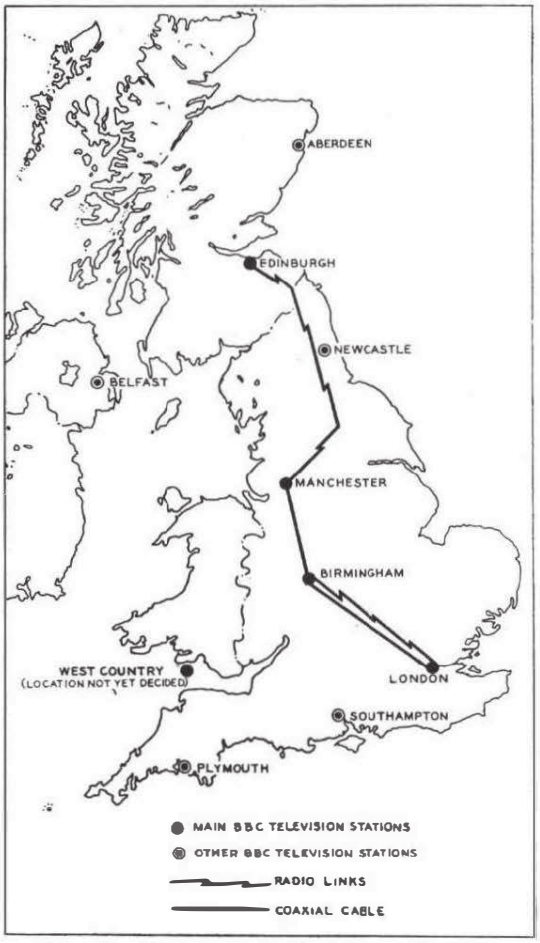


FIG. 19.—EXPANSION OF TELEVISION SERVICE.

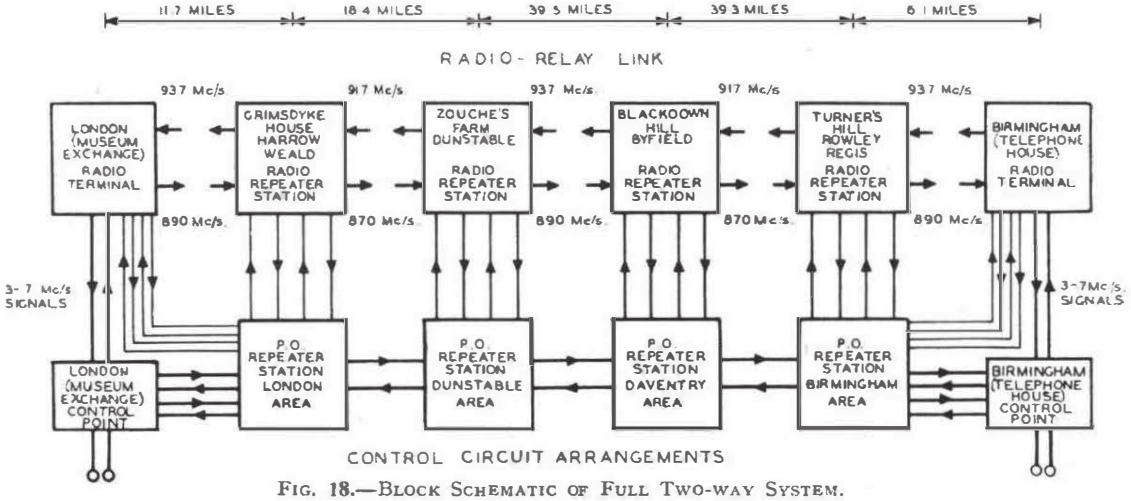


FIG. 18.—BLOCK SCHEMATIC OF FULL TWO-WAY SYSTEM.

from the relay links becomes more and more exacting if the cumulative effects of distortion in the component parts of the overall system are to be kept sufficiently low.

This article has outlined the position of the relaying of the present United Kingdom standard television transmissions. Doubtless at some time in the future a higher definition or, perhaps, colour will be demanded, with a consequent need for the transmission of still wider bands of frequencies to an even more exacting performance specification if the advantage of the higher definition is not to be lost. It seems likely that the advantages of radio will come even more to the fore with the demands for wider transmission bands. If, in the more remote future, the use of still wider frequency bands, maybe several hundred megacycles per second in width, becomes a necessity, it would seem that the waveguide method of transmission in which the signal will be transmitted (or guided) through a hollow metal tube, laid in the ground as coaxial cable is today, will be required. It will be apparent from what has already been said that the radio-relaying of wideband signals, whether using highly directional antennae and free-space transmission or using waveguide transmission, is destined to play an important part in the future.

Acknowledgments.

The development, production and installation of the London-Birmingham radio-relay system has been carried through by the General Electric Co., to whom we are indebted for much of the information contained in the brief description of the link.

We also wish to thank those many members of the Regional staff who have co-operated so willingly in helping our projects forward in so many different ways, appreciating as we do that the equipment for modern trunk systems is becoming so increasingly complex, whether or not the systems are radio, that they present a serious maintenance problem to the Regional staff.

Finally, we express our grateful thanks to our many colleagues in the Radio Branches whose efforts have contributed to the successful introduction of the television radio-relay link.

Bibliography.

[1] "A Micro-wave Relay System Between New York and Boston," A. L. Durkee, *Bell Laboratories Record*, December, 1947.

[2] "Terminals for the New York-Boston Radio-Relay System," J. G. Chaffee, *Bell Laboratories Record*, March, 1949.

[3] "New York-Boston Microwave Television Relay," *Electronics*, January, 1948.

[4] "A Broad-band Microwave Relay System Between New York and Boston," G. N. Thayer, A. A. Roetken, R. W. Friis and A. L. Durkee, *Proceedings I.R.E.*, February, 1949.

[5] "The Marconi-E.M.I. Television System," A. D. Blumlein, C. O. Browne, N. E. Davis and E. Green, *Journal I.E.E.* (Proceedings of Wireless Section), 1939, Vol. 14, No. 40, p. 65.

[6] "The Effect of Noise and Interfering Signals on Television Transmission," R. F. J. Jarvis and E. C. H. Seaman, *P.O.E.E.J.*, October, 1939, Vol. 32, p. 193.

[7] "A Microwave Triode for Radio Relay," J. A. Morton, *Bell Laboratories Record*, May, 1949.

[8] "The London-Birmingham Television Cable," H. Stanesby and W. K. Weston, *P.O.E.E.J.*, January and April, 1949, Vols. 41, p. 183 and 42, p. 33.

Book Review

"The Principles of Scientific Research." Paul Freedman, B.Sc., M.I.E.E., F.I.E.S. Macdonald & Co. (Publishers), Ltd., London. 222 pp. 11 ill. 15s.

The word "science" can have various meanings, yet it is evident that possession of knowledge is, by itself, no indication of that capacity for original thought which is an essential for successful scientific research. The author of this book is careful to give reasoned definitions of the meanings he gives to the words "science" and "scientific research" in the introductory part, which occupies the first three chapters. Taken as a whole, these chapters (60 pp.), outline influences of society and philosophy on scientific research, covering the whole span of recorded history and many branches of science. This remarkable feat of condensation is achieved by allowing the essential historical record to run through and by interspersing it with comment to bring out the points the author most wishes to make. It is interesting to note that the landmarks in the history of the methods of scientific research are not necessarily the same as those in the more familiar history of the product, scientific knowledge. A nice sense of proportion is maintained throughout the book and we share the author's regret that in consequence, the historical introduction cannot be given more space.

The remaining chapters contain advice and information concerning scientific research, primarily written for those who are inexperienced. Aspects covered include the personal qualities most likely to lead to success and lines on which these qualities should be developed and applied; the planning of research in relation to the nature of the problem and the resources and time available; use of the different senses for observations; choice of equipment; the strengths and weaknesses of team-work; relations between senior and junior scientists and between scientists and others concerned in their work (there is a chapter devoted to Patrons of Research); and accuracy of observations and economy of effort, related to which is a special mention of techniques for designing experiments so that the number of essential observations made is a minimum.

The underlying principles, which are the theme of the book could, when generalised to apply to the whole varied field of problems in scientific research, easily appear vague and unsatisfying. As treated, however, they are so well supported by the author's comment and explanation and illustrated by examples, mostly from his own experience, that the book is very readable. It should be read not only by those for whom it is primarily intended, namely young men and women embarking on research, but also by their more experienced colleagues and by those who have financial or administrative control of scientific researches. It is also worthy of notice by others who are interested in the capacity for thinking objectively in other fields of human activity.

W. W.

Testing Facilities in H.M.T.S. Monarch

P. R. BRAY, M.Sc.(Eng.), A.M.I.E.E.

U.D.C. 621.315.28

For the wide range of submarine cable work undertaken by the *Monarch*, comprehensive testing equipment and associated power supplies are necessary, together with test leads and intercommunication facilities so as to allow for tests to be conducted and controlled from a suitably situated testing room. In this article the author describes the equipment and testing facilities in some detail and outlines possible future developments in submarine cable testing technique.

Introduction.

SINCE H.M.T.S. *Monarch* was fitted out, experience gained in various aspects of deep-sea telegraph cable laying and repairing has led to modifications in the testing-room apparatus and circuits. That the modifications have, in general, been of a minor nature is a sufficient indication of the excellence of the original installation.[1]

In this article a description is given of the testing facilities as they are at present, without detailing the alterations that have been made, but it may perhaps be mentioned that the largest single change on the D.C. side is the provision of a guarding system, and in the A.C. bridge equipment certain additions and rearrangements have been made, with an improvement in the 230V A.C. power supply.

General.

The testing room (Fig. 1), measuring 15 ft. × 16 ft., is situated on the port side at the forward end of the shelter deck, with access from the centre castle and a view of the foredeck. The main test table (Fig. 2), accessible on three sides, is 12 ft. × 5 ft., and on this is mounted all the permanent D.C. apparatus. The A.C. bridge, with associated apparatus, is built up on a narrow bench against the after bulkhead.

The fore part of the room contains a desk, settee, filing cabinet and wash basin. Adequate cupboard space is provided for storing spare equipment and accessories.

Power Supplies.

The ship's supply is 220V D.C. balanced to earth, and an adequate number of points is provided in the testing room. For the battery supplies to the D.C. testing sets, accumulators are used, and these are charged from the ship's mains in a cupboard adjacent but external to the testing room. Reverse current relays protect the batteries against mains failure.

[1] Cable Test Report No. 1327 (restricted circulation).

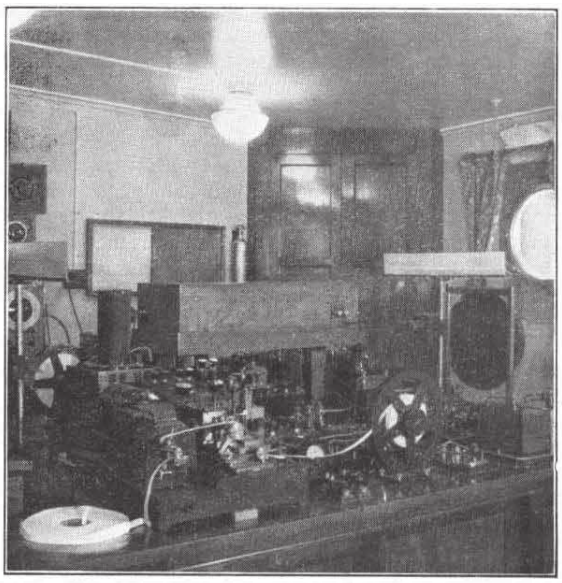


FIG. 2.—THE MAIN TEST TABLE, SHOWING SYPHON RECORDER AND D.R. TEST SET.

Two separate motor alternator sets, each of 800 W, provide the 230V A.C. 50 c/s supply needed by the bulk of the A.C. bridge equipment. These sets are housed in the thermo-tank room on the main deck, but apart from isolating switches all the controls are mounted in the testing room. The A.C. output is stabilised against variations on the D.C. side by rectifying a portion of the output and injecting it into the alternator field. Control of the output voltage is also given by means of a variable ratio transformer. Each alternator has its own panel of output sockets and transformer, so that an extra degree of decoupling between high- and low-level mains-driven apparatus can be attained if desired.

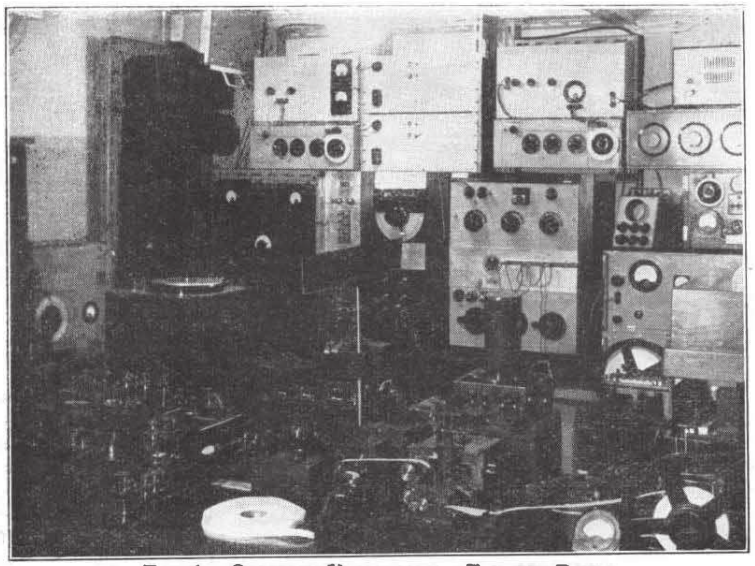


FIG. 1.—GENERAL VIEW OF THE TESTING ROOM.

Intercommunication Facilities.

A telephone on the ship's main internal system has five outlets, with push-button selection. These outlets are to the forward and after drum

rooms, the chart room, and to two suites which may be occupied by representatives of concerns chartering the ship. A separate telephone communicates with the bow and stern sheaves.

An audible signal may be made to each of the four cable tanks by means of bell-pushes, and in the reverse direction a bell signal may be received from the tanks, a drop indicator board identifying the tank. This bell system may be used according to any pre-arranged code, to indicate for example that a splice is about to be paid out, or in conjunction with the telephone leads associated with the tank testing leads.

Test Leads.

Six sets of permanent test leads are provided, connecting the testing room with the forward and after drum rooms, and with test boards adjacent to each of the four cable tanks. Each set consists of eight double-lead-covered rubber-insulated D.C. test leads (150-lb. conductor), two polythene-insulated coaxial cores with centre conductor of 508 lb./n.m. and copper return conductor for A.C. tests, and a 4-core 40-lb. lead-covered cable used chiefly for communication purposes.

At the far end of the leads (i.e., remote from the testing room) each of the D.C. and A.C. test leads terminates in a heavy slotted terminal mounted on an ebonite pillar. The D.C. leads are guarded by brass plates under the pillars, these plates being connected to the intermediate lead sheaths. The outer sheaths are connected together to form the earth return, and this " earth " may be connected to the hull earth as required. The guard system on each set of leads may be isolated from the rest and further sub-divided into two groups, should it be necessary to trace a fault in this system. The screens of the A.C. coaxial leads are brought out separately to terminals closely associated with their appropriate line terminals, in order that connections may be made with the minimum of added inductance.

Two flexible double-screened polythene coaxial leads are employed for connecting from any terminal board to the end of a cable These leads are used chiefly on the foredeck, to connect cable to the forward drum-room, particularly for tests just prior to a final splice. Similar type leads have been run from the testing room to cable tanks 1, 2 and 3, 4 (shared). These were installed before the guard system had been instituted on the normal test leads, at a time when it was necessary to make insulation tests on a long length of polythene cable with very high intrinsic insulation resistance. They will be useful in the future should it be necessary to make tests at high voltage.

In the testing room, all the sets of normal testing leads and the four-core leads terminate on a Paxolin panel mounted on the main testing table against the inboard bulkhead. Also connected to jacks on this panel are telephone leads from the Senior Testing Officer's cabin and from that of the Leading Jointer. The test board thus provides facilities for connecting up a Telephone " F " in the testing room with other parts of the ship, and also for interconnecting these places.

As with the terminal boards at the far ends of the leads, two earth terminals (outer sheaths of D.C. leads and the ship's hull) are provided. In addition, a guarded " line " terminal and " low potential " terminal are mounted on the board. The former is connected to the guarded line lead on the testing table, and may be joined to any terminal on the board by means of a flexible guarded lead. The latter is connected to the conductor resistance test set on the table, and may also be connected to any terminal on the board through a flexible lead. Except for loop C.R. tests on tank cable, it is normally connected to earth.

The line lead on the testing table is connected to a series of pillar-mounted sockets, each pillar being guarded. Any particular piece of equipment on the table may be connected to line by inserting a " petticoat " type plug in the appropriate socket. As only one plug is employed it is very unlikely that one test set would inadvertently be connected to line at the same time as another.

The Conductor Resistance Test Set

General Considerations.

Fig. 3 is a schematic diagram of the conductor-resistance test set connections. Basically it is a precision 5-dial Wheatstone bridge (thousands to tenths) suitably adapted for the particular nature of submarine cable testing, one of the main requirements being that the testing current should be easily controlled and set. This feature is considered later.

The line is connected to the bridge either directly or through a centre-zero milliammeter (30-0-30), with or without an added resistance, R4. This resistance is used in " overlap " tests when a cable is faulty but not broken. Switch S2 earths the line when the shore station is required to make a C.R. test to the ship. Normally the " low potential " lead is earthed when making single-ended tests, but it may be connected to the other end of the conductor when both ends of the cable are available in the ship, as in the loop tests on stock cable. Should a fault occur in a long length of such cable, S1 is used to earth the battery for a Varley test.

The bridge normally reads in International ohms, but an additional ratio arm has been provided in B.A. ohms* to give direct answers in these units if desired, the records of some cable systems being based on B.A. ohms.

Galvanometers.

Two galvanometers are permanently wired to the bridge via the galvanometer key, which short-circuits one when the other is in use. One galvanometer is of the " Unipivot " (pointer) type, with a sensitivity of 1·1 divisions per micro-amp. This is used for obtaining approximate initial balances, for routine C.R. tests when the ship is steady, and for keeping a continuous visual check of balance when picking up to an earth fault. The other galvanometer is more sensitive, being of the reflecting type. The sensitivity of the suspension and coil normally employed in this

* Resistance in B.A. (British Association) ohms = resistance in International ohms × 1·0136.

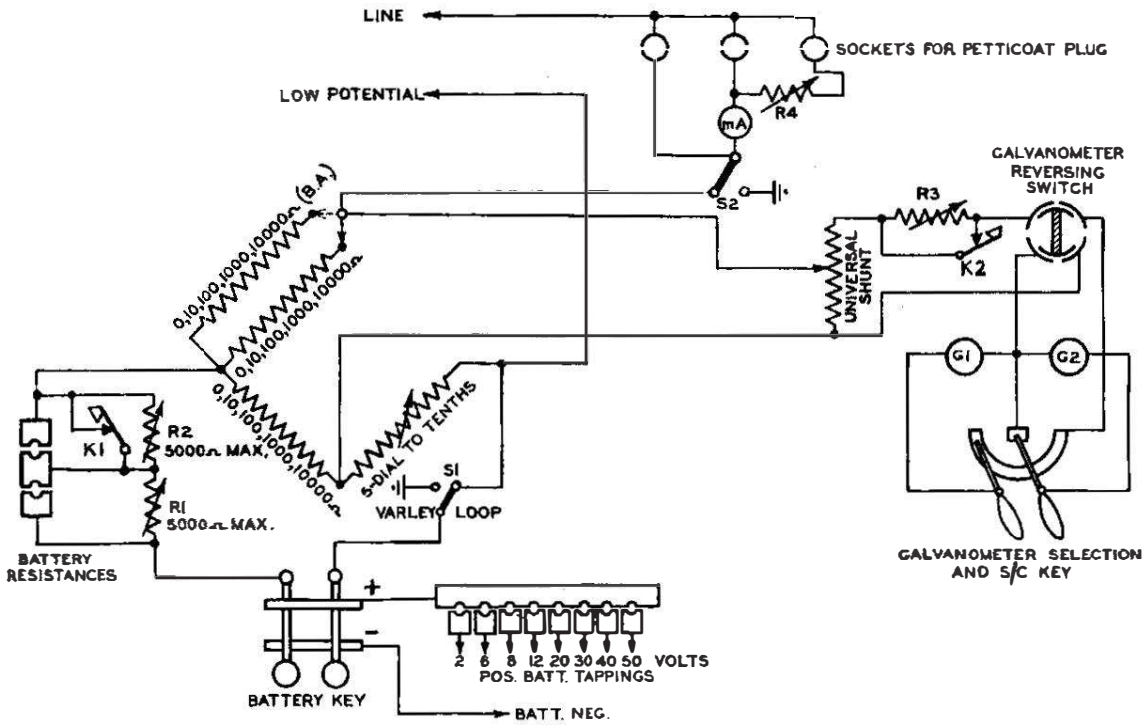


FIG. 3.—CIRCUIT DIAGRAM OF THE CONDUCTOR RESISTANCE TEST SET.

particular instrument is 40 mm. per micro amp. The coil carries small adjustable weights, by means of which the centre of gravity of the coil assembly may be brought exactly in line with the suspension. This ensures that there will be no appreciable rotation of the coil relative to the pole pieces when the ship rolls or pitches. Another important feature of this galvanometer is the wide range of control on the torsion head, which is used extensively in testing to False Zero or in Break tests as described below.

False Zero (or Cable Zero) Test.

When measuring the resistance of a single conductor, with one end only available at the testing station, it is necessary to use the earth as a return conductor. With the earth as part of the loop, it is at once apparent that any potential difference existing along the earth circuit will have an effect on the measuring bridge. Unfortunately, such P.D.s do exist, and they may be due to induced E.M.F.s in water moving relative to the earth's magnetic field, to interference from other neighbouring electrical circuits, or to magnetic disturbances. Spasmodic variations in the P.D. have to be tolerated, testing being carried out if possible in the quiet intervals, but the steadier components may be allowed for by observing their effect on the galvanometer deflection, and adjusting the bridge measuring resistance accordingly. Thus, at false zero balance, the deflection is the same whether the testing battery is applied or not.

It is important that the resistance of the network, as seen from the line, should not differ with the change in the battery conditions, and for this reason it is preferred that the resistors R1 and R2 used for controlling the testing current be connected on the bridge side of the battery key, so that they remain in circuit. It will be noted that in the false zero condition (i.e., battery key not operated) the low resistance battery is replaced by a direct connection, not a disconnection.

It may be found that the reflected spot of light moves off the scale under the influence of the earth P.D.s even with the galvanometer well shunted. As this would lead to an insensitive measurement, the torsion head is operated to bring the spot back on the scale as balance is approached, with the shunt opened up to full sensitivity if necessary. The electrical zero used in balancing may thus be very different from the mechanical or scale zero of the galvanometer. When testing a long line, it is not desirable that the galvanometer should be subject to the changes of charge brought about by the operations of the battery key, and it is short-circuited during such operations. It may sometimes occur that even so the galvanometer has to tolerate quite a violent change of conditions, owing to a big difference between the mechanical and electrical zeros. In such a case the short-circuiting of the galvanometer may be replaced by the opening of key K2, which puts the resistance R3 in series with it. Adjustment of R3 may be made to give a compromise between the two unwanted effects. Whether it is better to use R3 or the short-circuiting key depends on the circumstances, particularly with regard to the effect of galvanometer damping.

Testing to a Break.

When the copper conductor is exposed to sea water, it forms a cell with the iron of the armouring wires, the open circuit E.M.F. being about 0·5 V, with the copper positive. This cell polarises when current is

taken from it, so that its E.M.F. is not constant. Also, electrolysis takes place when current is passed through the cell, and the resistance so caused is dependent both on the strength and on the direction of the current.[2]

In order to measure the resistance of the conductor to a break it is necessary, therefore, not only to allow for any earth P.D.s and the E.M.F. at the fault, but also to eliminate the fault resistance from the value obtained on the bridge. Various tests have been devised with this latter object in view, all being based on the assumption that the variation of fault resistance with current may be determined. Resistors R1 and R2 are employed to give control of the current to line. The key K1 across R2 enables the current to be changed quickly from one value to another, and when so employed, with the battery key left down, results in a form of test called " reduced current zero." This is, in effect, a controlled false zero and, strictly speaking, the effect of the line voltages is different in the two positions of K1, owing to the change of resistance involved, but the error from this cause is not normally judged to be significant. For faults close to the ship, the resistance R4 is put in series with the line, as it is more convenient to have the bulk of the line resistance invariable with current.

It should be borne in mind that one effect at least, polarisation, is time dependent. Consequently, the electrical zero at which to balance is the position of the light spot after the initial kick due to inductive effects on changing the battery conditions, but before the spot drifts away under the influence of polarisation change.

The Insulation (Dielectric Resistance) Test Set

The circuit is shown in Fig. 4. The resistance to earth from the line terminal is measured by comparing the amount of current flowing with that which is passed by a standard resistance (1 megohm). The simple series circuits such as (*a*) and (*b*), shown inset in Fig. 4, illustrate the principle. In order that apparatus or surface leakages do not affect the reading, it is arranged that all such leakages must take place initially to a conducting guard system, which is connected to the junction of galvanometer and battery. The leakage currents then return to the battery without passing through the galvanometer. Each individual insulating pillar and piece of apparatus is so guarded where necessary.

The screws holding the pillars are tapped where possible through the guard plates, so that the sheet of metal is unbroken, and the metal itself is not lacquered. Surface leakage on the cable end is nullified by a few turns of bare wire (Price's guard ring) round the insulation, the wire being connected to the guard circuit.

A circuit change-over key is provided in order to set up circuit (*b*), with the galvanometer between battery and line, as this is sometimes requested by representatives of chartering companies. Otherwise, circuit (*a*) is preferred, because guard plates are of necessity exposed and bare, and any accidental earth on them short-circuits the battery in (*b*) but merely short circuits the galvanometer in (*a*). Provided that the battery is a compact unit, circuit (*a*) is more easily set up in portable equipment for use in situations such as cable huts, because the galvanometer circuit need not be guarded and need have only reasonable insulation.

The dielectric resistance test is made with each direction of current in the line, to allow for the effect of earth P.D.s. The algebraic mean of the deflections is taken when calculating the dielectric resistance, after allowing for the fact that the positive direction of galvanometer deflection reverses with the reversal of current.

It is not correct to calculate the resistances separately and then take the mean. If the two readings be considerably different, the deflection with no battery is taken to check whether the change of reading is due to earth P.D.s.

[2] *Munro and Jamieson's Pocket Book*, p. 331.

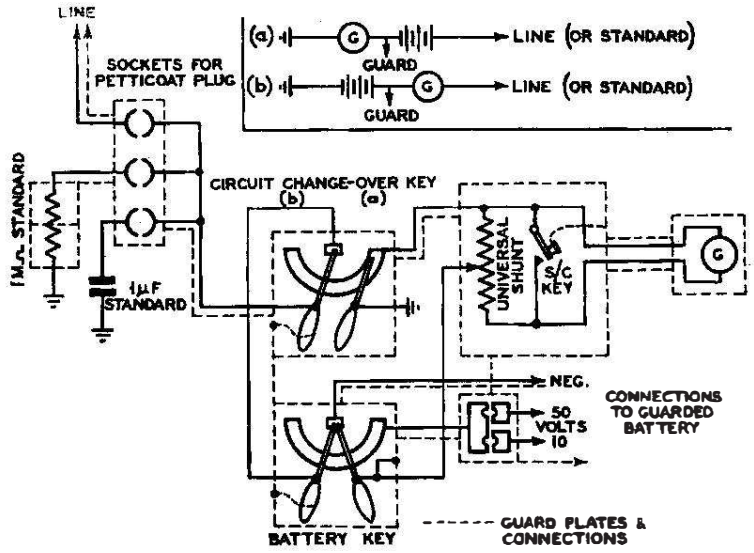


Fig. 4.—Circuit Diagram of the Insulation (Dielectric Resistance) Test Set.

Much can be learnt from the effect of the line on the D.R. set as to the possible existence of an incipient fault. To allow for the charging of the cable, it is usual to note the deflections at intervals over a period of two to five minutes, and to observe the general behaviour of the light spot over the same period.

On gutta-percha cables two voltages are normally employed, 10 for old and 50 for new. These suffice for obtaining definite insulation values, except on very short lengths. The balanced, reflecting type galvanometer is used with a centre zero scale, and has a sensitivity of 22 mm. per micro amp. Although the galvanometer is not ballistic, it may be used to give reasonable measurement of capacitance by " throws " on lengths up to about 50 nautical miles. The use of the D.R. set for capacitance measurement is particularly useful on very short lengths,

and no throw is obtained from the guarded leads. A standard 1 microfarad capacitor is included for calibrating the galvanometer.

D.C. Capacitance Test Set

The two most generally accepted methods of measuring the D.C. capacitance of long cables are those of Kelvin and Gott. The latter is rather quicker, but has a disadvantage in the way in which the different time-constants of the line and standard capacitor affect the obtaining of a balance. Attempts to make the time-constants more nearly equal may lead to the balance being controlled to a certain extent by the resistances added to the network. It is difficult to see why Kelvin's method of mixtures has tended to be superseded by Gott's method, and the former is the test employed in *Monarch*.

Fig. 5 shows the circuit used. The line is charged from part of the slide wire, and the standard capacitor from the remainder. After 15 to 30 seconds the slide wire is disconnected and the charges allowed to mix for a similar time, the residual charge then being put through a galvanometer. Balance is obtained by varying the slide position until the residual is zero or negligibly small. In practice, the balance point may be accurately estimated once two reasonably close positions have been noted giving residuals of opposite sign and known relative magnitude, as judged by the direction and magnitude of the galvanometer throw. It is usual to make the test with the two polarities of battery (10 V or so) in order to reduce any error due to earth P.D.s.

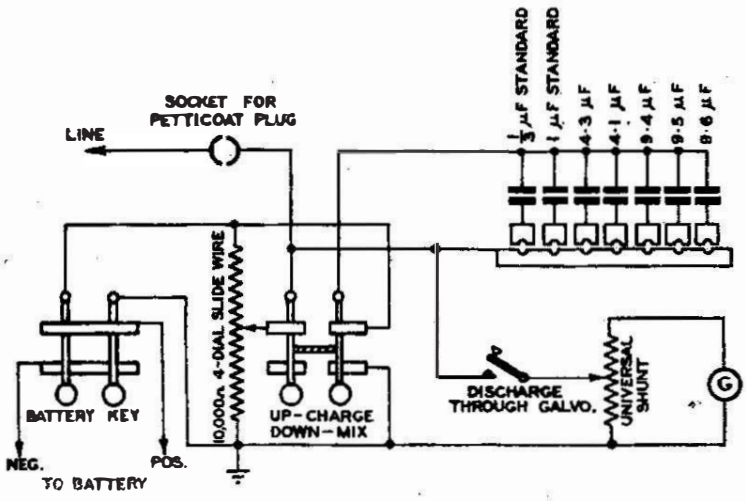


Fig. 5.—Circuit Diagram of the D.C. Capacitance (Mixture) Test Set.

The reflecting galvanometer employed is more ballistic than those previously referred to, and has a current sensitivity of 380 mm. per micro-amp. It is not balanced, but little difficulty is experienced in observing " kicks " superimposed on slow movements due to the roll and pitch of the ship.

Reference to Fig. 5 will show that the main difference in the circuit compared with the mixtures-test circuit, as usually drawn, is that earth is connected directly to one end of the slide wire (4 dial). The battery is connected across the slide through the usual type of key, the leads being kept entirely independent of the charge-mix key wiring except at the junctions on the slide terminals. The insulation resistances to earth of the battery and one side of the standard capacitor merely shunt the whole slide wire. The cable insulation shunts the lower end of the slide, and if necessary the value of the standard capacitance may be kept rather low in order that the slide is near the bottom end at balance, thus reducing the shunt error. The insulation to earth of the slider side of the standard capacitor should be good and also, of course, the intrinsic insulation of the capacitor itself. In practice no trouble has been experienced due to low insulation on this part of the circuit. Should this occur, it is possible by the use of a standard, smaller than the capacitance to be measured, to work with the standard right across the slide wire, with only a slight extra complication in the keying arrangements.

Two standard mica capacitors of $\frac{1}{3}$ microfarad and 1 microfarad respectively are used with the set. Other mica capacitors, which are recalibrated at suitable intervals, enable larger capacitances to be obtained.

Recorder, A.C. Bridge and Miscellaneous Apparatus

Recorder Circuit.

Signalling is carried out by a form of Morse code with " dots " and " dashes " of equal length but opposite polarity, a syphon recorder being used for the reception of signals. This is essentially a moving-coil galvanometer; passage of the signalling current deflects the coil, which in turn causes an ink-carrying glass syphon to mark a trace on a moving slip of paper. The circuit, shown in Fig. 6, is that of the long-distance recorder. A capacitor may be inserted in series in the receive condition to provide a rough degree of equalisation, to restore signal shape. This is rarely used on the ship, as sensitivity is seriously impaired unless the capacitance is made considerably larger than the 10 microfarads shown. A less sensitive recorder is also available. The circuit is similar to Fig. 6 except that no capacitor is included, and an adjustable resistance is put in series with the line to reduce the current on short cables. Using both recorders is an advantage when testing to stations at both ends before a final splice, as continual adjustment of shunts and battery powers is avoided.

A.C. Bridge.

The A.C. bridge is used in the localisation of faults by the impedance/frequency method, and also, when opportunity serves, in determining the constants of various sizes and types of cable.

A schematic diagram of the bridge and associated apparatus is given in Fig. 7, and indicates the facilities available for connecting up the oscillator and detector units to the bridge by plug-ended cords.

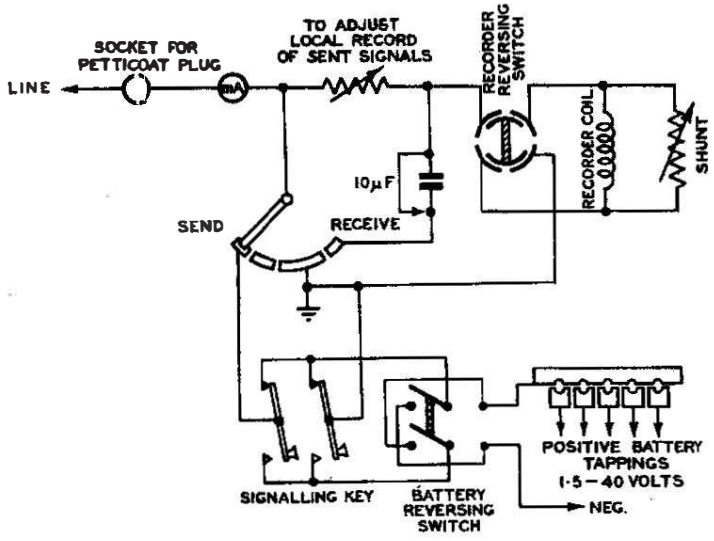


FIG. 6.—CIRCUIT DIAGRAM OF THE LONG-DISTANCE RECORDER.

With the exception of the heterodyne detector all the units are mains driven, the power packs for the sub-audio oscillator and amplifier being of particularly low impedance.

As far as can be foreseen, *Monarch* is likely to have to deal with unbalanced cable only, and the bridge is, therefore, wired with one point earthed. The impedances to be dealt with vary over a wide range of modulus and angle, and a large degree of flexibility of interconnecting components is required. Furthermore, the range of frequency required is also very wide, so that a ratio-arm bridge is preferred. This has the advantage of being satisfactory up to the highest frequency employed (111 kc/s), which has been found to be adequate, while enabling very low frequencies (down to 1 c/s) to be used if required.

Normally the ratio arms are each of 1,000 ohms, but it is possible to change over to 100 ohms should these give an advantage, such as when making tests at carrier and high audio frequencies where the characteristic impedances of the cables are of the order of 40-60 ohms.

To obtain the flexibility of interconnection already referred to, a system of jacks and low-capacitance keys is used, although this is an expedient that is normally best avoided in precision A.C. bridge work. However, attention has been paid in the wiring layout to reduce to a minimum inductance and capacitance errors. Where accuracy in absolute measurements is required, substitution methods are employed. This is particularly necessary at sub-audio frequencies, where in any case a series-artifice bridge (added capacitance in series with the line) has to be resorted to in order to measure the large capacitance component of the cable impedance.

In the impedance/frequency method of fault localisation the impedance measured by the bridge will differ from the characteristic impedance, provided that the wave reflected from the fault is not unduly attenuated during its passage back to the sending end. If the received reflected voltage is in phase with the sent voltage, the impedance will be a maximum, and the respective currents are out of phase. When the converse applies, the impedance will be a minimum. The phase is dependent on the total phase-change along the cable to the fault and back, and provided

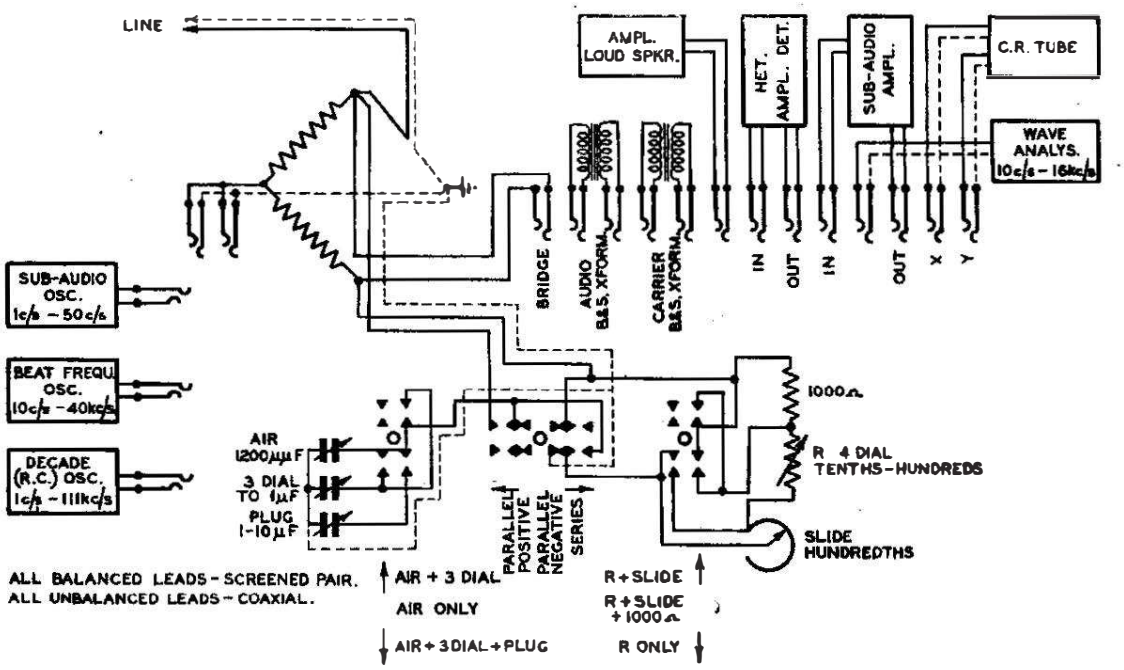


FIG. 7.—SCHEMATIC DIAGRAM OF THE IMPEDANCE BRIDGE.

that the phase constant per unit length of the cable is known, the distance to the fault may be determined once the total phase change has been found. In practice, it is best to observe the alteration in total phase change with frequency by measuring the sending-end impedance over a suitable frequency range, the modulus of this impedance passing alternately through maximum and minimum values. Since the difference in total phase change between successive maxima (or minima) is 2π radians, and the corresponding frequencies f_1, f_2 are known, then

$$\beta_2 2x - \beta_1 2x = 2\pi$$

where β_1, β_2 are the phase constants of the cable in radians per nautical mile at f_1 and f_2 respectively, and x is the distance to the fault in nautical miles. (It is assumed that the phase change at the fault does not vary significantly with frequency.)

A typical value for the velocity of propagation at carrier frequencies of a gutta-percha submarine cable is 70,000 n.m. per second, and the wavelength in n.m. at 110 kc/s is then about 0·64 n.m. This means that the frequency is adequate to enable a difference of 2π radians in phase-change to be measured on 0·32 n.m. of cable, or π radians (working between a successive maximum and minimum, or vice versa, on the sending-end impedance frequency characteristic) on 0·16 n.m. of cable. As the ship would invariably pick up to any fault within this distance, the limiting condition is satisfactory.

It can be shown that, for a fault giving practically a full reflection, the phase-change to the fault and back will always be at least 2π radians when the cable attenuation to the fault is 27·3 db. If the bridge and associated apparatus is sufficiently sensitive to detect changes in impedance at this attenuation distance, the corresponding limit of physical distance is governed by the capability of measuring at sufficiently low frequencies.

It is for the purpose of investigating the possibility of localising faults up to 1,000 nautical miles from the ship that the sub-audio apparatus has been installed. The output of the tuned amplifier connected to the bridge is fed to the Y-plate amplifier of the cathode-ray tube, with the oscillator giving a horizontal sweep on the X-plates. At balance there is no vertical movement of the trace, except that due to harmonics (when present) and these are clearly distinguished from the fundamental by the distinctive pattern.

The wave-analyser is used as an amplifier-detector on the bridge for low frequencies above the range of the sub-audio apparatus, and is a useful alternative to the other detecting equipment up to 16 kc/s.

The interpretation of results obtained at very low frequencies, compared with that at higher frequencies, is made more difficult by the rapid change of characteristic impedance with frequency, and by the fact that the velocity of transmission is itself frequency-dependent. Whatever frequency range is involved, however, it is almost always useful to recognise the fact that the phase constant, β, becomes indefinitely small as frequency decreases towards zero, thus giving one known point on all phase-constant/frequency cable characteristics.

Miscellaneous Apparatus.

Two portable self-contained D.C. testing sets are carried for boat or beach work, in addition to spares for the main components of the D.C. sets in the testing room. These latter components are useful in connecting up for such tests as the Murray, which are required only infrequently.

For the location of the line of a cable, a search coil is available for beach work, and a 17 c/s amplifier-detector for use in the ship when towing electrodes. Satisfactory results have been obtained using standard paragutta 508/690 core with bared ends as electrodes.

Should the ship be required to work on multicore cables, the usual quad-switching and terminating devices are available, and attenuation and crosstalk sets may be built up.

Future Developments.

One troublesome factor in the measurement of conductor resistance on cable coiled in the tanks is the variable E.M.F. caused by the turns moving relative to the earth's magnetic field, when the ship rolls or pitches. Where possible, separate lengths of cable are joined up so that their induced E.M.F.s are opposing. In order to have a counter E.M.F. available at all times, it is proposed that a single turn of multi-core cable be laid round each tank. The conductors will be joined in series to give an effect similar to many turns of cable. It is not certain how serious residual phase difference will be, but it can possibly be overcome by using both the number of turns of the " ballast " coil and a potentiometer to get the right magnitude of counter E.M.F. The induced E.M.F. in tank cable also makes it more difficult to observe the dielectric resistance in the earlier stages of a long laying operation.

Another improvement, especially when laying a long cable, will be to have the cable engine revolutions repeated to the testing room. With a suitable make and break device, it has been found possible to operate meters of the subscriber's type. It is hoped also to arrange for the temperatures of the tanks to be read at any time on a meter in the testing room.

It is intended that pulse apparatus shall be tried for the quick localisation of faults near the ship. The utility of this type of apparatus will be restricted by the high attenuation of normal sizes of telegraph cable. If, in order to increase the range, lower frequencies than those employed in pulse apparatus designed for land coaxial cables are used, then considerable distortion of the received pulse must be expected, both on account of the attenuation/frequency and the velocity/frequency relationships.

Acknowledgments.

It is desired to thank the Commander and the Submarine Superintendent for permission to publish this article. Thanks are also due to Mr. W. H. Reynolds, Mr. R. Pharo and other colleagues for assistance at different times, and to the Chief Electricians of Cable and Wireless, Ltd., who have served in the ship from time to time as representatives.

A Method of Reducing the Vibration from Diesel Engine Generating Sets

J. H. ALDERSON, M.A., A.M.I.E.E.

U.D.C. 621.313.322-84 : 621-752.2

This article describes the various types of objectionable vibrations likely to be set up by a diesel engine driving an electric generator. The problem is considered theoretically and a method of mounting the bedplate on springs or other resilient material in order to reduce the amplitude of the vibrations is described. The article is illustrated by photographs of some recent Post Office standby diesel engine generating sets mounted in this manner.

Introduction.

THE widespread and increasing use by the Post Office of stationary diesel engine generating sets to provide standby electricity supplies to important buildings has drawn attention to the noise and vibration which such machines cause. This problem has been accentuated by the introduction of engines running at higher and higher speeds, viz. 1,000 r.p.m. and even 1,500 r.p.m. Speeds of this order present very different problems from the 200-300 r.p.m. of the earlier single- and twin-cylinder horizontal diesel engines, which were such a familiar sight in the early repeater stations, where they were frequently the only source of electricity supply. A standby engine can with advantage be designed to run at a higher speed than an engine which is the sole source of power to a building and must be run continuously for long periods. The higher speed enables a more compact engine requiring less accommodation to be installed, but more elaborate measures may be required to deal effectively with the vibration caused by the engine.

This article deals mainly with the case of diesel engine generating sets installed in Post Office buildings, but the methods described below may be extended to apply to all types of rotating and reciprocating machinery and impact machines such as power hammers and drop stamps.

Vibration.

Vibration is inherent in the design of reciprocating machinery, and is due to the horizontal and vertical forces caused by the unbalanced reciprocating and rotating masses and, in the case of internal combustion engines, to the explosive effects as the fuel is ignited and burnt. Improvement to an extent depending on the number of cylinders in the engine can be effected by means of balancing and this is done as a normal part of engine design. The first harmonic can be eliminated by balancing the rotating masses of the cranks, but the higher harmonics are not normally dealt with as the problem is too involved and costly. The higher harmonics can, however, be avoided, in some cases entirely, by selecting the number of cylinders, e.g. dynamic balance can be obtained with a 6-cylinder engine. In the case of the 4-cylinder engine, there is an appreciable second harmonic, which is not normally balanced, although in very exceptional cases where perfect balance is essential it can be eliminated by incorporating twin rotating masses rotating in opposite directions and driven at twice the speed of the engine through crank shaft gearing.

The problem is accordingly to reduce the inherent undesirable vibration to an amount that can be tolerated without inconvenience. In extreme cases it will be necessary to reduce the vibration to prevent damage to the surrounding building and the machine itself.

The vibration will be perceptible partly as noise and partly as movement, and may be analysed as follows:—

(i) Air vibrations are heard as noise and consist of primary and secondary air vibrations. Primary air vibrations are transmitted directly by the machine to the surrounding air and are heard only in the machine room and the immediate vicinity. Secondary air vibrations are caused at any point by the transmitted foundation vibrations.

(ii) Foundation vibrations are produced in the foundations and transmitted with high efficiency throughout the building, to adjacent buildings and the ground itself, where they may be detected as movement or secondary air vibrations.

Foundation Vibrations.

The various types of vibration transmitted by a machine not isolated from its foundations are shown in diagrammatical form in Fig. 1. Care must be

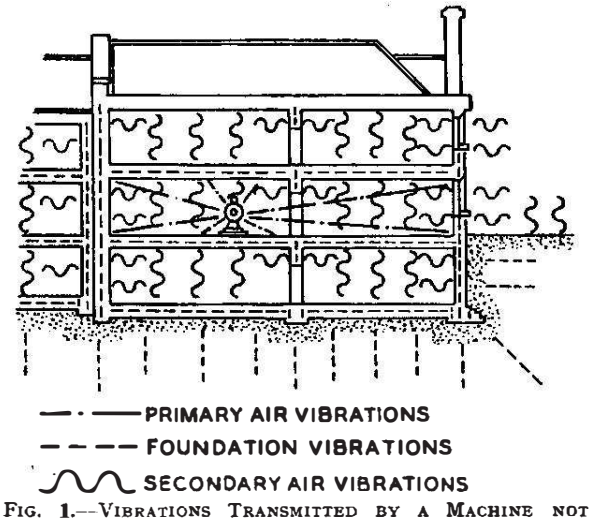


FIG. 1.—VIBRATIONS TRANSMITTED BY A MACHINE NOT ISOLATED FROM ITS BED.

taken not to confuse secondary air vibrations with primary air vibrations when the former happen to be of the same frequency as the latter. Consideration of the layout of the building should enable the two types of air vibration to be distinguished in such

cases. Foundation vibrations may be transmitted long distances and reappear as noise or hum. Measurement of the fundamental frequency will, in most cases, enable it to be traced to its source.

The effect of isolating a machine from its foundations is shown in diagrammatical form in Fig. 2. The

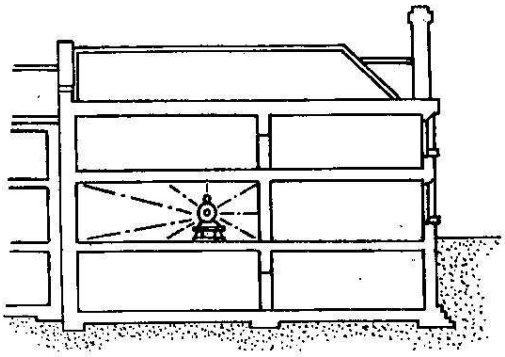


FIG. 2.—EFFECT OF ISOLATING MACHINE FROM ITS BED.

transmission of the foundation vibrations from the machine to its foundations has been stopped and consequently the secondary air vibrations have been eliminated. Further, the intensity of noise in the machine room will have been reduced, and this can be prevented from spreading by suitable sound-proofing of the room if required.

From the foregoing it will be seen that the problem resolves itself into the prevention of the transmission of the foundation vibrations. This can be done to a greater or lesser degree by interposing some form of elastic material between the machine and its foundations. It will be helpful at this point to consider the problem dynamically and determine the equation of motion of a mass supported on a spring subject to a forced vibration.

Theoretical Treatment.

Fig. 3 shows a mass M supported on an elastic

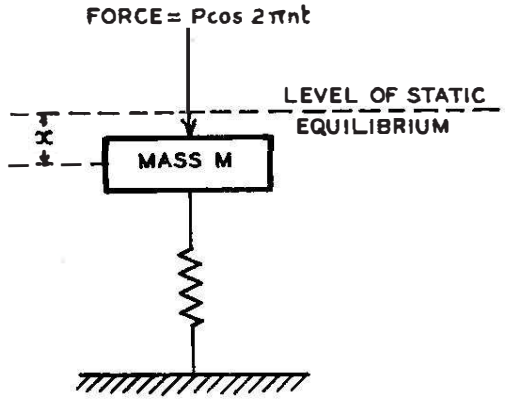


FIG. 3.—FORCED VIBRATION OF A MASS SUPPORTED ON A SPRING.

spring and acted upon by a force P varying harmonically with a frequency n.

Suppose that the strength of the spring is such that when the compression is x, the force in the spring is μx.

Then the equation of motion is :—

$$M \frac{d^2x}{dt^2} = -\mu x + P \cos 2\pi nt$$

$$\text{or } M \frac{d^2x}{dt^2} + \mu x = P \cos 2\pi nt$$

The complete solution of this differential equation is :—

$$x = A \cos \sqrt{\frac{\mu}{M}}\, t + B \sin \sqrt{\frac{\mu}{M}}\, t + \frac{P \cos 2\pi nt}{\mu - 4\pi^2 n^2 M}$$

Let $\sqrt{(\mu/M)} = 2\pi n_o$,

where n_o is the natural frequency of vibration of the spring and mass M. This gives

$$x = A \cos 2\pi n_o t + B \sin 2\pi n_o t + \frac{P \cos 2\pi nt}{\mu(1 - n^2/n_o^2)}$$

Consider the motion where M starts from rest from the position of static equilibrium :—

(i) When $t = 0$, $x = 0$ $\therefore A = -\frac{P}{\mu} \cdot \frac{1}{1 - n^2/n_o^2}$

(ii) When $t = 0$, $\frac{dx}{dt} = 0$ $\therefore B = 0$

Now let $P/\mu = e$, where e is the compression of the spring produced by a steady force P.

Equation of motion now becomes

$$x = \frac{e}{1 - n^2/n_o^2} (\cos 2\pi nt - \cos 2\pi n_o t)$$

In actual practice the second term, representing the natural frequency of the system, will be associated with a damping factor and will be eliminated after an interval of time. The state of steady motion will, therefore, be represented by

$$x = \frac{e}{1 - n^2/n_o^2} \cos 2\pi nt$$

From this it will be seen that the effect of the spring in reducing the amplitude of vibration of the mass M, and thus the force tending to cause foundation vibration, will be considerable where n/n_o is large, i.e. where the natural frequency of the spring and mass is small compared with the frequency of the disturbing force. If n is less than n_o the vibrations will be magnified, while if $n = n_o$ a dangerous condition of resonance will be set up.

Reduction of Vibration.

To be of any practical value in reducing the amount of the vibration caused by a machine, therefore, the characteristics of the elastic foundation material must be such that the natural frequency of vibration of the machine on the elastic material is well below the frequency of the forced vibrations. From this it follows that a method of preventing the transmission of the higher frequencies will not necessarily prevent the transmission of the lower frequencies, although a method of preventing the transmission of the lower frequencies will also prevent the transmission of the higher frequencies.

Elastic Foundation Material.

Two types of elastic material can be used to isolate a machine from its foundations :—

(i) A layer of cork, felt or rubber may be placed under the concrete foundation block forming the bed of the machine, or directly under the machine bedplate if this is suitable and stiff enough to withstand any torsional stresses imposed upon it by the machine.

(ii) Specially designed springs with a low natural frequency of vibration may be used in place of the layer of elastic material to support the machine.

In order to give some idea of the amount by which the transmission of vibration may be reduced by these methods, the two following examples will serve as illustrations.

First, consider a four-cylinder engine running at 800 r.p.m. mounted on a layer of cork subjected to a loading of 1 ton per sq. ft. The natural frequency of the cork will be about 1,000 per minute, and the principal frequency to be suppressed will be the second harmonic of 1,600 per minute. The ratio of reduction is

$$\frac{1}{1 - (1{,}600/1{,}000)^2} = \frac{1}{1{\cdot}56}$$

or approximately 35 per cent.

Second, consider a machine with an out-of-balance frequency of 750 per minute mounted on springs having a natural frequency of 150 per minute under a loading of 10 cwt. The ratio of reduction is

$$\frac{1}{1 - (750/150)^2} = \frac{1}{24}$$

or approximately 95 per cent.

In practice the reduction will be less than the calculated value. With the maximum practicable difference between natural frequency and that to be suppressed, reductions of 65 per cent. for cork and 90-95 per cent. for springs may be expected. By mounting the machine on a concrete bed of large mass, the energy of the unbalanced forces is partially absorbed in moving the mass, thus reducing the amplitude of the transmitted vibrations. The improvement to be gained in this direction, however, is strictly limited by the cost and physical dimensions of the concrete block.

Anti-vibrators.

A patented type of spring mounting, designed by the firm of Messrs. W. Christie & Grey, Ltd., has been on the market for a number of years, and is very effective in reducing foundation vibrations produced by all types of machine. This is known as the "Anti-vibrator" and the pedestal type is shown in detail in Figs. 4 and 5.

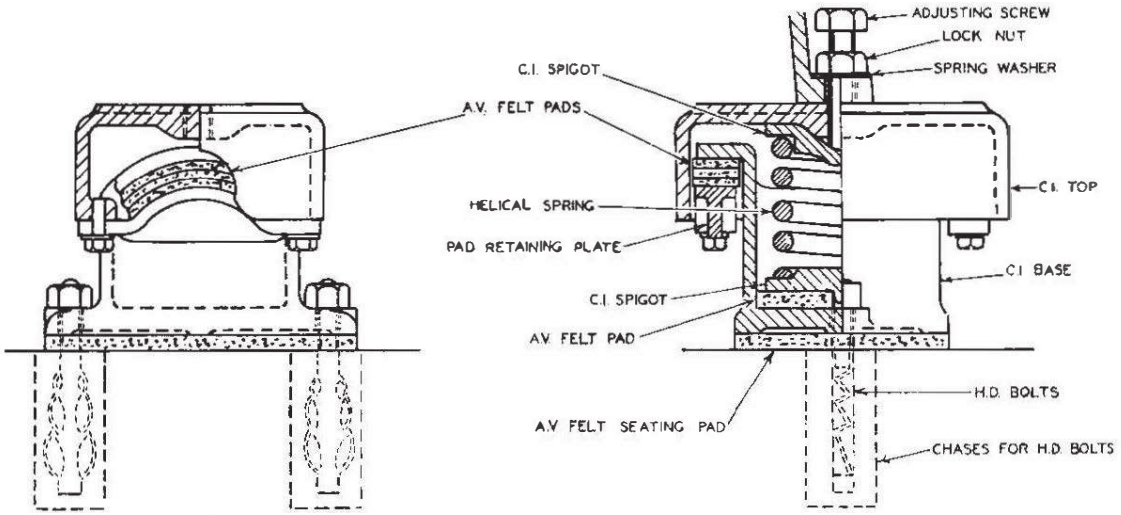


FIG. 4.—CONSTRUCTION OF A TYPICAL PEDESTAL-TYPE ANTI-VIBRATOR.

The top portion of the anti-vibrator is bolted to the base of the machine and the bottom portion to the floor. The main isolating medium between the two halves consists of a helical spring designed to have a natural frequency under load well below the out-of-

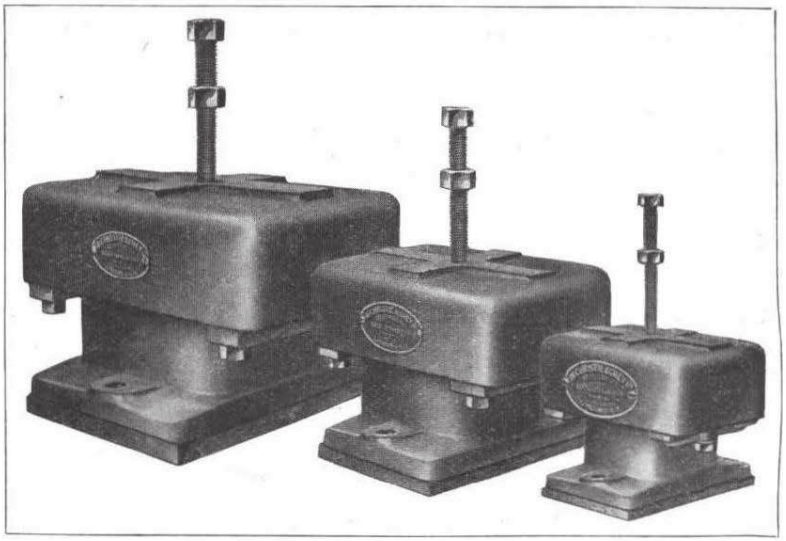


FIG. 5.—PEDESTAL-TYPE ANTI-VIBRATORS.

balance frequencies of the machine. In addition, anti-vibration felt pads are placed beneath the spring and the base of the unit to attenuate any high or audible frequencies which may pass through the spring steel. The two felt pads in the form of an arch at the sides of the unit will look after any horizontal out-of-balance forces. The most efficient adjustment of the anti-vibrator is when the side felt pads are just in contact with the base of the unit.

The bridge-type anti-vibrator, shown in Fig. 6, is

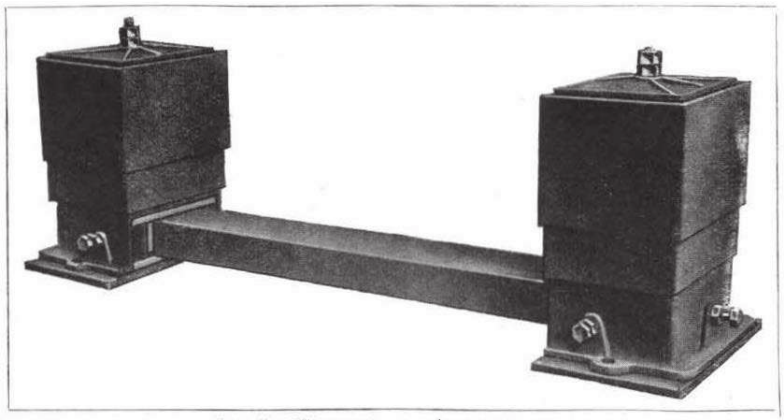


FIG. 6.—BRIDGE-TYPE ANTI-VIBRATOR.

an alternative arrangement which can be used with advantage when headroom is restricted. The machine is bolted to the steel channel section forming the bridge, the ends of which are supported on springs and felt pads operating on the same principle as the pedestal type.

Resonance.

It will be noted that the machine will pass through the resonant frequency of the springs whenever it is started up and shut down, but provided these operations are performed as quickly as possible no damage will occur. Vibrations of appreciable amplitude will be set up, but these will die away very rapidly as soon as the resonant frequency is passed. Care must be exercised to ensure that the resonant speed is passed through quickly, as vibrations of a dangerous amplitude will be rapidly built up if there is any hesitation near the resonant speed. This should be a most unlikely occurrence, however, as springs should never be used for low-speed machines, and the resonant speed will be only a small fraction of the normal running speed of the machine.

Some Post Office Installations.

In 1947, it was decided to purchase a number of diesel engine generating sets to serve as standby sources of power to safeguard the services in important buildings in case of power failure or load shedding. Several firms received bulk allocations of steel and other materials to enable them to make large numbers of standard sets and delivery was obtained more quickly than would have been the case had sets been ordered specially for each requirement. The sets were self-contained, being mounted on a heavy fabricated steel bedplate on which was included a simple switchboard to control the output of the generator.

The Post Office bought forty sets from Messrs. Davey Paxman, Ltd., each consisting of an 80-h.p. 4-cylinder diesel engine running at 1,000 r.p.m. direct-coupled to a 65-kVA, 400-V, 3-phase, 50-c/s, 0·8 power factor alternator with belt-driven exciter mounted upon it.

The sets are transportable as units and do not require specially prepared foundations. This was of considerable advantage as it was desired to have the sets in service as quickly as possible without having to wait for elaborate foundations to be prepared. Another consideration was that a number of the sets would probably be required in the buildings to which they were first allocated for a limited period of time, after which they could be transferred elsewhere. It was therefore desirable to keep the cost of the foundations to a minimum and their design as simple as possible to facilitate later removal.

Under these circumstances, the use of anti-vibrators had everything in its favour and it was decided to install the whole of the 40 sets on anti-vibrators. The sets weigh approximately 4¾ tons and are mounted on 10 anti-vibrators, each capable of carrying a load of 10 cwt. Fig. 7 shows the anti-vibrators installed on the existing basement floor ready to receive the 65-kVA set at Clerkenwell exchange.

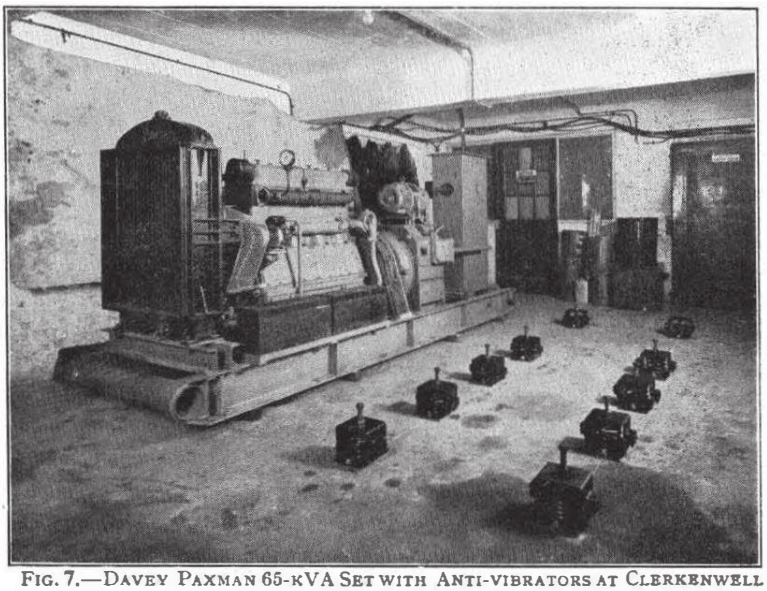


FIG. 7.—DAVEY PAXMAN 65-KVA SET WITH ANTI-VIBRATORS AT CLERKENWELL EXCHANGE.

These anti-vibrators differ from those illustrated in Figs. **4** and **5**, being of a simpler prefabricated type, due to the difficulty in obtaining the necessary cast iron castings at that time. The essential components are the same, however, and they are equally effective in reducing vibration from the sets.

A completed installation at Museum exchange is shown in Fig. **8**. In addition to the anti-vibrator

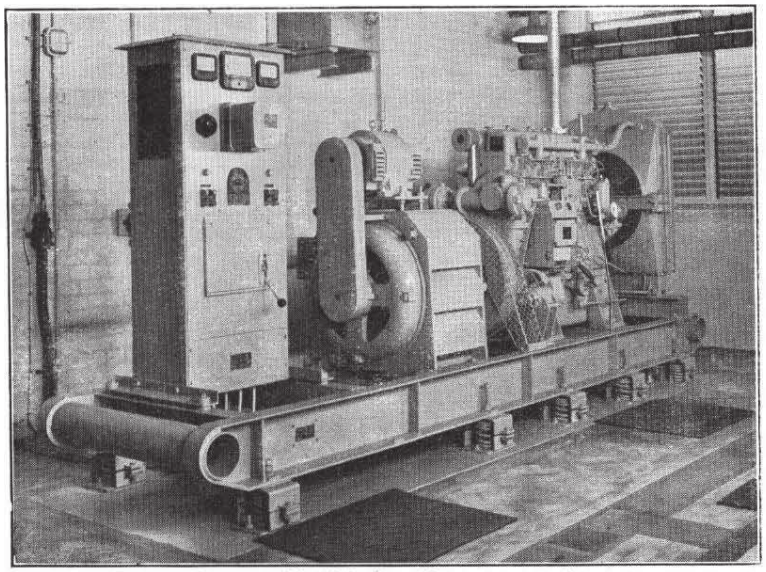


FIG. 8.—DAVEY PAXMAN 65-KVA SET MOUNTED ON ANTI-VIBRATORS AT MUSEUM EXCHANGE.

spring mountings, all connections to the set, i.e., cable in conduit, exhaust, fuel oil and cooling air, are flexible connections to prevent any transmission of vibration. The set runs very smoothly, and the amount of vibration transmitted to the building is negligible. As mentioned earlier, the set does rock noticeably when it passes through the resonant frequency of the springs on being run up to speed or shut down, but the springs are able to look after this transient condition.

For mainly similar reasons the standby sets in the four intermediate relay stations on the London-Birmingham Television Radio-Relay Link have also been mounted on anti-vibrators. Each of these sets consists of a Ruston and Hornsby 30-h.p., 3-cylinder diesel engine, running at 1,000 r.p.m. direct-coupled to a 20-kVA, 0·8 power factor alternator with mains voltage characteristics. Each set is mounted on ten 5-cwt capacity anti-vibrators, and the complete installation at the Dunstable relay station is shown in Fig. **9**.

Early Application of Anti-vibrators.

When the writer was preparing the material for this article the following very interesting early application of the use of anti-vibrators in the Post Office was brought to light. It appears that in the old Portsmouth T.E. the motor-generator sets for battery charging were installed upon an upper floor of the building and caused a considerable amount of vibration. So many complaints were made locally that in the end the machines were mounted on anti-vibrators. This occurred in 1915 and was apparently completely successful. The reason for the excessive vibration was probably that the speed of the motor generator sets was the same or very close to the natural frequency of vibration of the floor on which they were installed. Isolation of the sets would prevent the floor from vibrating, and in an extreme case would prevent damage being caused to the fabric of the building.

Conclusion.

In conclusion, the author would like to thank Mr. W. B. Grey of Messrs. W. Christie & Grey, Ltd., for his kindness in providing information and the drawings and photographs for Figs. **1**, **2**, **4**, **5** and **6**.

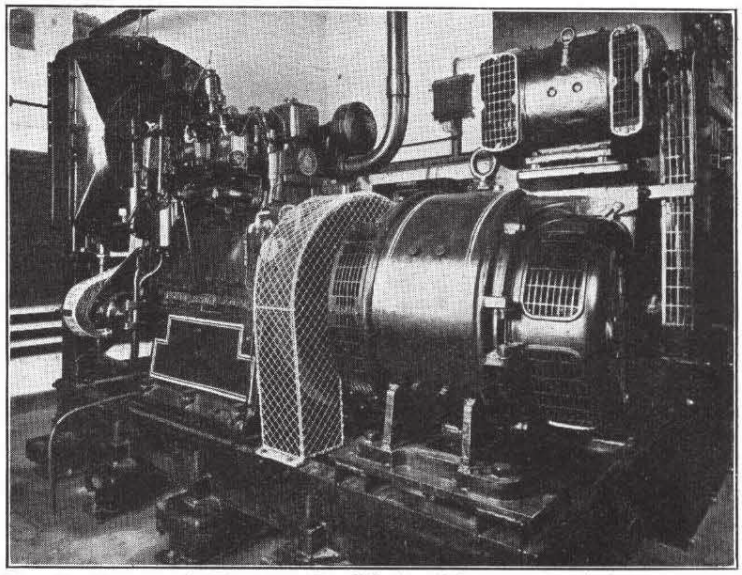


FIG. 9.—RUSTON & HORNSBY 20-KVA SET MOUNTED ON ANTI-VIBRATORS AT DUNSTABLE TELEVISION RELAY STATION.

Book Reviews

" Aerials for Metre and Decimetre Wavelengths." R. A. Smith, M.A., Ph.D., A.M.I.E.E. Cambridge University Press (Modern Radio Technique Series). 218 pp. 125 ill. 18s.

This book is mainly about aerials for the " metric " (1 m to 10 m) range of wavelengths, but a short chapter on aerials for the range 0·1m to 1·0m is included. Aerials for the " centimetric " range are to be dealt with in a companion volume.*

Aerials used for the metric range comprise dipoles, used singly and in arrays, Yagis, slots and long-wire aerials such as rhombics and Vees.

Aerials for the metric range of wavelengths are of considerable interest to Post Office radio engineers since many of the Department's single and multi-channel radio telephony links between the mainland and islands, e.g. Chaldon-Guernsey and Holyhead-Douglas, operate in this range.

The present book contains not only the basic theory of metric aerials but also much information of an essentially practical kind derived from the author's wide experience with radar aerials at the Telecommunications Research Establishment, Ministry of Supply. It is perhaps a minor criticism of the book that most of the examples of aerial design selected to illustrate the theory are drawn from radar practice; the book would have been more generally useful had aerials for sound and television broadcasting and for mobile and point-to-point communications systems also been described.

However, the book is thoroughly recommended not only for the clarity of the theoretical treatment, but also for the considerable amount of practical information, much of it hitherto unpublished, which is presented.

W. J. B.

* " Aerials for Centimetric Wavelengths," by D. W. Fry and F. K. Goward, Modern Technique Series, Cambridge University Press.

" Pulses and Transients in Communication Circuits." Colin Cherry, M.Sc.(Eng.), A.M.I.E.E. Chapman & Hall, Ltd. 317 pp. 129 ill. 30s.

Anyone familiar with Mr. Cherry's works will expect this book to be refreshing and instructive, and they will not be disappointed. The last ten or fifteen years have seen very big changes in telecommunications engineering, due largely to the introduction of television, radar and time-division systems. Where formerly very few of us needed to consider the transient behaviour of networks, nowadays it is often a vital and sometimes a troublesome part of our work—troublesome because, as Mr. Cherry says in his preface, much that has been written on the subject " is in the form and style of professional mathematicians."

Strangely enough, the first chapter, which is devoted to introducing and solving the differential equations that form the basis of network theory, is a little disappointing and the discussions and explanations, so obviously intended to make the treatment simple, are so long that one is liable to lose the thread of the argument.

After considering the frequency spectra of recurrent and non-recurrent waveforms a general study is made of the steady-state properties of two- and four-terminal networks. Having thoroughly prepared the way, the author goes on to discuss the time responses of passive networks to pulses of different shapes and to suddenly applied sinewaves. Although the treatment is generally very good there is one part that is misleading. It is implied on pages 168 and 170 that, in practice, low-pass filters cannot be made to have the same skew-symmetrical response to a Heaviside Unit Function as an idealised filter that cuts off sharply and has no delay. But low-pass filters are not infrequently designed to have a fairly sharp cut-off with a substantially constant phase delay up to and beyond the cut-off point, and the response of such a filter approaches that of the ideal network very closely. The point that the author and others seem to have overlooked is that if the phase delay of a network is substantial, the main part of the response can be preceded by ripples without requiring the ripples to appear at the output before the stepwave is applied to the input! The whole subject of low-pass networks with linear phase characteristics, i.e. constant phase delay, through the cut-off is of great importance in television.

The treatment of the steady-state and transient behaviour of asymmetric sideband systems is clearer and more comprehensive than in any other book that has come to hand, which is fortunate as the subject is difficult and asymmetric sideband operation is used in this country for relaying television over cables and for television broadcasting itself. Further subjects discussed include the time responses of amplifiers, the effects of echoes, and the estimation of time-response distortion in terms of amplitude and phase distortion using the method of paired echoes, another subject on which most text books are silent. The value of the present publication is increased by the extensive bibliographies, containing 20 to 30 references, that appear at the end of each chapter. The author has carefully avoided making the subject more mathematical than is absolutely necessary; his object was to write a book for television and radar engineers, not for mathematicians, and as an engineer the reviewer congratulates him on his success.

I.P.O.E.E. Library No. 1891. H. S.

" Principles of Microwave Circuits." Vol. 8 in the Radiation Laboratory Series (Massachusetts Institute of Technology). Edited by C. G. Montgomery, R. H. Dicke and E. M. Purcell. 486 pp., 293 ill., McGraw-Hill Publishing Co., Ltd., 36s.

This book deals with the application of Maxwell's electromagnetic field equations to the analysis of microwave circuit elements such as waveguides with inductive slit and capacitive diaphragms, resonant irises, tuning devices, resonant cavities, waveguide junctions with multiple arms including the " magic " or hybrid T, directional couplers and similar devices. Where possible use is made of the normalised impedance concept and the equivalent circuit representation of microwave circuit elements.

The engineer looking for a ready-made solution to a specific microwave circuit problem will probably not find it in this book; what he will find is a statement of the general theoretical principles from which solutions to specific problems may be derived. Practical solutions of the latter kind are given for example in the " Waveguide Handbook" (Vol. 10 of the Radiation Laboratory Series). It is because of the fundamental nature of the treatment of the subject that the present volume is likely to be of considerable and permanent value to those concerned with the design of microwave equipment; in other words, it provides a basis for tackling new problems not dealt with in text-books of less fundamental scope.

This work has all the clarity of exposition, thoroughness and accuracy that one has come to expect of the Radiation Laboratory Series and is confidently recommended to physicists, engineers and mathematicians interested in electromagnetic field problems at microwave frequencies. W. J. B.

" Receivers." Stanley K. Lewer, B.Sc. The Radio Society of Great Britain, London, 1949. 96 pp. 98 ill. 3s. 6d.

This small publication, together with a similar volume dealing with transmitting equipment (see below) have both been prepared and published under the general editorship of John Clarricoats, the General Secretary of the R.S.G.B., and are companion volumes to others already produced. The aim of this booklet dealing with receivers is to explain to the novice the general fundamental principles, and to a large extent it succeeds. There are a few criticisms. For instance, on page 14, the term " cross modulation " is suddenly introduced with no explanation as to what it is and reference to the index shows no reference to the term. On page 20, Figures 24 and 25 have been interchanged with unfortunate results. The illustrations are profuse and clear, the inclusion of an occasional photograph being most helpful. An extensive bibliography is provided, but the method of arrangement in chronological order, in which the original articles appear, rather detracts from its utility. R. J. H.

" Simple Transmitting Equipment." W. H. Allen, M.B.E., and J. W. Matthews. The Radio Society of Great Britain, London, 1949. 44 pp. 20 ill. 2s.

The make-up of this book is similar to that of " Receivers," and again the general editor is John Clarricoats. The aim is to present simple transmitting equipment and associated apparatus in a readable, non-mathematical manner, the method of treatment being to devote the first chapter to fundamentals, the second to aerials and the remaining chapters to constructional details of specific pieces of apparatus. This method of presentation apparently absolved the authors from the necessity of providing an index. Diagrams and photographs are plentiful and layout drawings are given which enable the would-be constructor to reproduce accurately the various transmitters, etc., described. It is pleasing to see such points as the importance of good earthing arrangements for components stressed and the chapter devoted to aerials gives the reader a general outline of the subject. Altogether it may be said that this little volume provides much useful information at an extremely reasonable cost. R. J. H.

" The Mathematics of Circuit Analysis." E. A. Guillemin. John Wiley & Sons, Inc., New York (Chapman & Hall, Ltd., London). 590 pp. 120 ill. $7.50.

Many branches of communication engineering cannot be adequately studied without the use of mathematical techniques which are outside the scope of most engineering and many mathematical curricula. This book, the fourth in the " Principles of Electrical Engineering " series, by members of the staff of the Massachusetts Institute of Technology, is intended to supplement the normal training of electrical engineers, and the authoritative standing of Professor Guillemin, both as a teacher and as a worker, is sufficient guarantee of a high standard.

The book begins with a study of various advanced algebraic topics associated with linear systems, in four chapters on Determinants, Matrices, Linear Transformations, and Quadratic Forms. A chapter on Vector Analysis follows. The last two chapters, which occupy respectively about a third and a quarter of the book, are on Functions of a Complex Variable and on Fourier Series and Integrals. Each chapter is accompanied by a large number of problems (some 300 altogether), often designed to bring out further theorems not explicitly mentioned in the text.

It will be seen that the subjects treated are comparatively few and can thus be dealt with in fair detail, in as much detail, in fact, as in many of the smaller treatises. The last two chapters, in addition to dealing with general foundations, select various advanced topics which have particular applications to circuit analysis.

Since the book is intended for engineers, mathematical rigour is not insisted upon, but heuristic arguments and appeals to geometric intuition, backed up by the illustrations, are constantly used to make the argument easier to follow ; this does not mean, of course, that the various mathematical subtleties associated with limits, convergence, and the like are ignored. Although frequent references are made to practical applications, especially to network synthesis, transients, and potential fields, no attempt is made, either in the text or in the problems, to give a full analysis of any particular practical question.

The various subjects dealt with can, in general, be found in an appropriate mathematical text-book, but the selection of those branches applicable to circuit analysis, and the manner of presentation, will make this book very acceptable to communication engineers. W. E. T.

" Permanent Magnets." F. G. Spreadbury, A.M.Inst.B.E. Sir Isaac Pitman & Sons, Ltd., London. 280 pp. 173 ill. 35s.

This contains more detail than would be needed in a student's text-book ; it may fairly claim to be a work of reference, the first in English on the technical aspects of modern magnetic materials. For this role it is well qualified by excellent contents pages and clear cross-headings throughout the book ; on the other hand the index is incomplete, and there is a shortage of references to other books or original papers (there are only 25 such references in the whole book, of which 11 are to the works of one author, Mr. F. G. Spreadbury).

Chapters on the properties and applications of the various alloys, both old and new, are practical in outlook ; the alloys are clearly listed and classified, and the scope is broad enough to include oxide magnets and other pressed materials. These chapters would, by themselves, justify the book's existence.

The elementary theory of magnetism is given in the conventional form, with no solution to the usual difficulties—H is " of the same nature as B " so why measure one in oersteds and the other in gauss ? The chapter on magnetic measurements makes a rather sudden transition from our old school-friends, the A and B positions of Gauss and the plotting of a B-H loop, to the design of search-coils for testing loudspeaker magnets. On this subject the " Dictionary of Applied Physics," though old, is still excellent, and might well have been quoted as a reference. The discussion of magnetic leakage starts well ; but it leads into calculations, based on artificial assumptions, which are of interest chiefly as exercises in the integral calculus ; surely empirical methods would be used in practice ? A chapter on quantum theory is in strange company ; the approach used in academic atomic physics is inconsistent with the engineering outlook of the rest of the book, notably the Preface which says that " magnetism is fundamentally due to electric currents."

Most of the diagrams are good and clear, but they have no titles, and many of them therefore compel a search through the text to discover just what is being illustrated ; perhaps this is intentional, but it is irritating in a reference book. The author's English is sometimes careless and sometimes inflated. Here, then, is a book that is worth having, but not as good as it easily might have been. A. C. L.

Notes and Comments

Recent Awards

The Board of Editors has learnt with great pleasure of the honour recently conferred upon the following member of the Engineering Department :—

Lincoln Telephone Area	Jackson, F.	Technician Cl. IIA	Lieut.-Commdr. R.N.V.R.	Officer of the Order of the British Empire

New Year Honours

The Board of Editors offers congratulations to the following members of the Engineering Department honoured by H.M. the King in the New Year Honours List :—

Engineering Department ..	Hillman, W. J. ..	Technical Officer	British Empire Medal
Engineering Department ..	Unitt, A. T. G. ..	lately Motor Transport Officer, Cl. I	Officer of the Order of the British Empire
London Telecomms. Region..	Brockwell, A. H.	Inspector	British Empire Medal
Swansea Telephone Area ..	Coles, W. H. A.	Inspector	British Empire Medal
Tunbridge Wells Telephone Area	Scott, F. W. ..	lately Technician	British Empire Medal

Sir Thomas Purves

We regret to record the death of Col. Sir Thomas Fortune Purves, which occurred on 29th January, in London, in his seventy-ninth year.

Sir Thomas entered the Civil Service in 1889, and transferred in 1892 to the Post Office Engineering Department, in which he had a most distinguished career, culminating in his appointment in 1922 as Engineer-in-Chief. He held this position for ten years, at a time when rapid technical development was providing the means for linking up distant towns in Great Britain and on the Continent by means of a network of trunk cables, and for setting up a world-wide radio communication service. He will be remembered at home and abroad for the ability with which he directed the application of these developments, as well as for the leading part he played in bringing about the introduction of automatic switching in the local telephone field.

A knighthood was conferred on him in 1929, and in the same year he was elected President of the Institution of Electrical Engineers.

On retirement from the Post Office in 1932, Sir Thomas became Managing Director of United Telephones, Ltd., and later, Director of the Cable Makers' Association, a position which he held until retirement in 1948.

Mr. L. G. Semple

Mr. L. G. Semple, at one time Chief Regional Engineer, Home Counties Region, was promoted (*in absentia*) to Regional Director, North Eastern Region, in 1945, while seconded to the Control Commission, Germany, as Controller-General, P. & T. Division. It is regretted, therefore, that in the last issue of the Journal a notice appeared indicating that this promotion was of recent date, and apologies are offered for the error.

Institution of Post Office Electrical Engineers

SUBSCRIPTIONS DEDUCTED FROM OFFICIAL SALARY

Change from Annual to Monthly Deductions

Most members of the I.P.O.E.E. have agreed to avail themselves of the facility afforded by the Department of having their Institution subscriptions deducted from official salary, an arrangement which is of convenience both to individual members and to the Institution as a whole. Under the existing method, members' subscriptions are deducted in one sum annually during the June salary month.

The methods by which subscriptions to various National or Departmental organisations—such as the I.P.O.E.E.—are deducted from pay, have recently been considered by the Treasury, and it has been found that deductions can be more easily dealt with at the pay centres if the amounts are resolved into monthly sums. To meet the Treasury recommendation, the Council of the Institution has agreed that from the beginning of the 1950/1951 Session, I.P.O.E.E. subscriptions which are deducted from official salaries shall be deducted at monthly rates instead of by one annual sum. The total amount of the annual subscription will remain unchanged for all classes of the membership.

As from the 1st April, 1950, the annual 17s. 6d. subscription due from the class of Member will be deducted at the rate of 1s. during the month of April, and 1s. 6d. each month during the months of May to March inclusive. The annual 15s. subscription due from the classes of Associate Member and Associate will be deducted at the rate of 1s. 3d. each month during the months of April to March inclusive.

(*Continued on page* 59)

Regional Notes

Midland Region

GROWTH OF TREE ROOTS IN 4-WAY DUCT

Following a fault on the Birmingham-Ashby M.U. cable, an attempt was made to rod a spare way in the 4-way duct preparatory to drawing in a length of cable for the temporary repair. Rodding operations were, however, unsuccessful and an interruption length was laid overground to restore service. When the faulty length was withdrawn further attempts were made to rod. It was found that two spare ways were completely blocked and the way previously occupied by the faulty length was partially obstructed.

TREE ROOT FORMATION.

The ground was excavated to expose the duct track, one duct removed and the remaining ducts slipped back over the cables one at a time. It was then found that a root of a nearby willow tree had entered the joint between two ducts, grown into all four ways and the firing bore, and filled them with tightly packed fibrous root for a distance of thirty yards. Some idea of the obstruction caused can be obtained from the photograph which shows lengths of the fibrous root actually removed. The lengths have been inserted into a spare 6-way duct for illustration purposes. E. S. L.

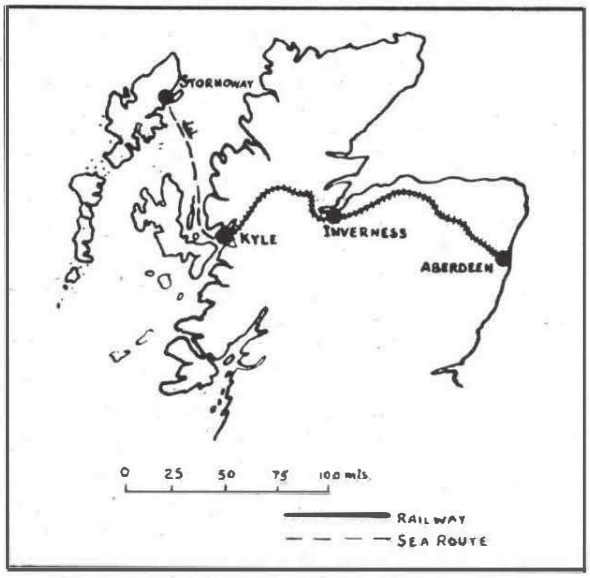
Scotland

STORM DAMAGE IN THE HEBRIDES

A snowstorm of unusual severity, accompanied by violent lightning, swept over Lewis and Harris in the Outer Hebrides on Friday, 9th December, 1949. Peat bog is common in the Islands, the result being that with the heavy wind and ice-loading some 200 poles were badly deflected and seven miles of junction route and 200 miles of wire will need complete rebuilding.

Several exchanges were isolated. At Callanish (famous for its Druid Standing Stone Circle), the D.P. snapped and the leading-in cables pulled the entire window frame out of the Post Office building—much to the consternation of the Postmaster.

The main object of this note is to give some idea of the difficulties to be faced in emergency restoration work on islands. All available Wire, C.C. 70 lb P.V.C. Army-type



MAP SHOWING ACCESS TO STORM DAMAGE AREA.

and interruption cable was despatched from Aberdeen to Kyle of Lochalsh (200 miles) in two special vans attached to the first available passenger train. A landslide affecting the railway line resulted in the vans being two days en route. Fortunately, 16 miles of P.V.C. had been sent to Kyle of Lochalsh by Departmental road transport and one ton of 150-lb. copper and some interruption cable had reached Kyle by an earlier train from Inverness. This material was shipped to Stornoway without delay and filled the breach until the main consignments arrived. Two external construction gangs working in Skye were transported by road and ferry to Kyle where they were met by an Inspector from Inverness. The party joined the Kyle-Stornoway steamer and embarked upon a rough 70 mile sea journey across the Minch to reinforce the resident maintenance and construction staff in Stornoway.

All stores had to be shipped via Kyle which proved to be a veritable bottleneck—the daily steamer being capable of taking only a limited quantity of freight in addition to its usual cargo of essential foodstuffs, mails, etc., for Lewis. The result was that in spite of strenuous efforts on our part it was the following Tuesday night before any appreciable quantity of interruption cable reached the island and the stores from Aberdeen, together with supplies of cable and wire from Depot, piled up on the dock side. In the end the local staff at Kyle had to sort out the items most urgently required and ensure that they obtained priority of shipment.

The Army-type wire was found to be extremely useful in effecting temporary restoration of service; being wound double with approximately one loop mile per drum, paying out was a speedy process. The joints were kept well clear of the ground. The only difficulty so far experienced has been that the island sheep——voracious animals—seem to have a liking for the P.V.C. insulation. H. J. R.

Home Counties Region

" TESTS AND PESTS "

With the systematic inspection of pole routes and the consequent increase in pole renewals, a great deal of interest has been paid to the decayed portions of timber. On cutting a decayed section from the sound timber, it was noted that the affected portion had been extensively honeycombed. Further examination revealed that a large grub had been thriving on the wood decay and, as a matter of interest, it was passed to the Essex Institute of Agriculture at Writtle, near Chelmsford.

A report has been received from the British Museum that the larva is in the group of the largest British Longhorn beetle, known to zoologists as " Prionus Coriarius." It is uncommon for telephone pole wood to be infected by this larva and doubtless it came from some nearby infected tree stump.

A further item of interest covers the use for odd lengths of stainless steel aerial cable. On a number of occasions the local cabling network at a large well-known factory had been affected by rodents, which damaged the lead cable where it leaves the internal cable chase to a 2-in. pipe leading to a joint box. The damage was always at the point where the cable enters the pipe, which had been effectively sealed, and it was thought that the rats on being poisoned attempted to follow the cable route in search for water.

In spite of the efforts of the management to dispose of the rats, some effective measure was necessary to prevent disruption of the telephone service, and the trouble has been satisfactorily cleared by renewing the faulty cables with odd short lengths of stainless steel aerial cable at the point where the lead cable had been continually affected.

L. G. H.

South-Western Region

BOURNEMOUTH AUTOMATIC AREA

The first stage of conversion to automatic working was completed successfully on 30th November 1949. General restriction on new buildings explains a modest commencement with two satellite exchanges and a tandem exchange, the latter installed in the building used for the Telephone Manager's Offices. A third exchange is due for conversion to satellite in 1952. Although plans for solution of a thorny problem at the Central exchange, Bournemouth, are well advanced, the date for completion is in the lap of the Ministry of Works! Bournemouth multi-office area thus becomes the first to be provided with multi-metering on conversion from manual, but as the tandem exchange has no subscribers' multiple the provision of non-metering relay sets is adequate for the equipment fitted in this building; nevertheless, in the allocation of dialling codes the standard arrangement for non-director areas has been made. The absence of multiple at the tandem exchange gave rise to a number of problems affecting the service circuits in the same building, particularly to the maintenance control which was, in common with all other service lines in the building, connected to the Central (Bournemouth) exchange, the latter retaining manual working initially.

The conversions at Boscombe and Canford Cliffs have been effected in each scheme as a turn-round in the existing buildings, and the temporary alterations to manual equipment and cable racking in the apparatus rooms to permit a satisfactory layout of the automatic plant called for much ingenuity. Subsequent to the transfer the maximum precautions were taken to prevent dispersal of dust to the automatic equipment by the use of vacuum cleaners and dust sheets (the close proximity of new and old equipment prevented the erection of partitions).

Efforts are being made to make the maximum use of the automatic equipment already provided and hopes for further extension are maintained but, with 23,000 working lines within a 5-mile radius of the main exchange, the task ahead remains formidable.

M. C. S.

Welsh and Border Counties Region

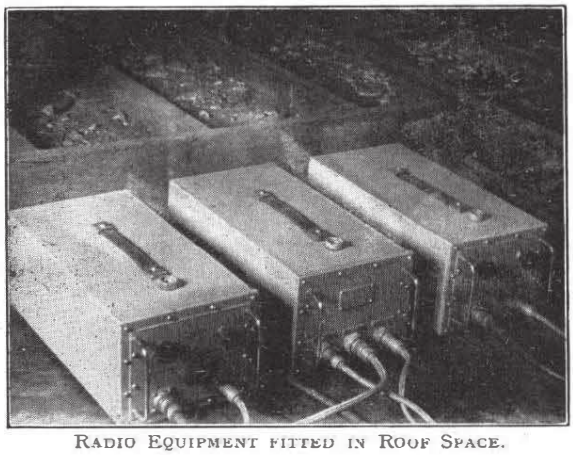
TENBY-CALDY RADIO TELEPHONE LINK

For some considerable time the necessity has been felt for a reliable means of communication between the Island of Caldy and the mainland. Communication has been provided in the past by means of a submarine cable which was abandoned and then by the Coastguards working by medium wave R/T to the Coastguards at Tenby. This method has proved unsatisfactory, due to the difficulty of maintaining a continuous watch.

A decision was made by Headquarters early in 1949 to install, at Tenby and Caldy, terminals of the new V.H.F. inter-island telephone equipment on an experimental basis for six months. If satisfactory operation was obtained, the Area would take over complete maintenance.

A full description of the equipment has been given by Messrs. Hollinghurst and Sowton in the paper on "V.H.F. Communication," delivered to the I.E.E. in 1949. It is sufficient to state that it is entirely battery-operated from dry and wet Leclanché cells which, with normal operating conditions, will give a life of approximately four months. Facilities are provided for C.B. and auto-signalling and supervisories.

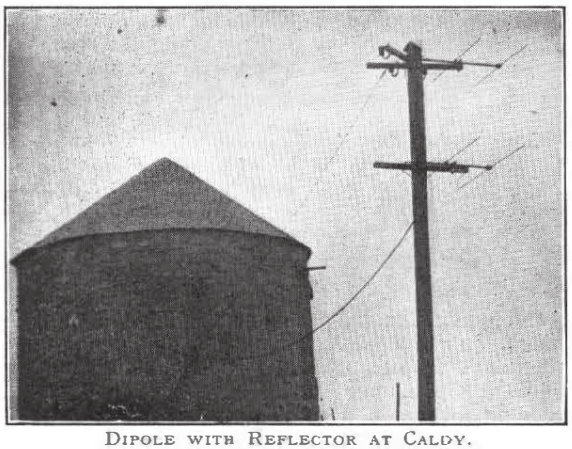
The Area was asked to co-operate with the Engineer-in-Chief's Radio Branch on the installation in October, 1949. Equipment accommodation was found at Caldy in the basement of the "Chapel of Our Lady" and at Tenby in the roof space. The aerials, a dipole with reflector at Caldy, were mounted on a 24-ft. medium pole, which forms part of the overhead 2-wire route to Caldy Sub Post Office. At Tenby they are mounted temporarily on a steel roof standard.



RADIO EQUIPMENT FITTED IN ROOF SPACE.

The installation was completed by the end of October and, after some experimental work, was opened for public service on the 7th November, 1949. The popularity of the circuit has exceeded all expectations, and during the months of December and January, 464 outgoing and 218 incoming calls were passed from and to the Caldy S.O. The signal-to-noise ratio of the circuit is sufficiently high to allow calls to be extended to the

Inland and Continental trunk networks with satisfactory results.



DIPOLE WITH REFLECTOR AT CALDY.

The fault liability of the equipment has proved to be reasonably low and it is expected that maintenance will be handed over to the Area in May of this year.

Caldy is so well known that the successful establishment there of the first-ever public telephone circuit of this type is worth reporting. E. M. B.

North-Western Region

LIVERPOOL—KIOSK CONSTRUCTION

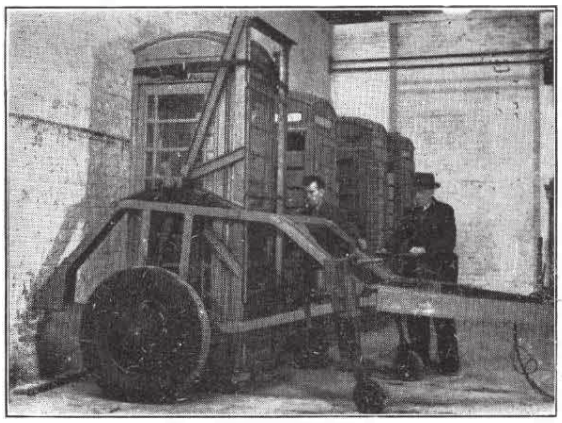
Delays in organisation at one time made the provision of telephone kiosks a protracted operation, and at the beginning of 1948 the whole of the arrangements were examined with a view to reducing such delays to a period more in keeping with the length of time it takes to do the actual work. The first stage was in the co-ordination of the siting proposals so that the Sales, Development, and Electric Light and Power Groups could determine the site in conjunction with the Surveyor and the Electricity Authority with a minimum of correspondence.

Originally, after the site was determined, the kiosk fabric was erected and instructions were passed for the connection of electric light cable and telephone wires, and the kiosk was put on the list for painting. In this way, the kiosk would stand idle for three months or more, waiting the provision of services before the equipment could be installed, and the appearance was a direct invitation to the rougher elements to smash the windows. During the course of the investigation, it was also found that as much as thirty-five pounds was charged by the Electricity Authority to arrange for the disconnection and reconnection of the electricity supply when a kiosk was being renewed, due to the special precautions necessary when there is any delay between demolition and reconstruction. It was decided to approach the Local Authority to agree on adopting a new method which would leave the fuse box supported on a template with the fuses withdrawn during renewal.

The ultimate plan, therefore, was to set up a paint factory for the painting of assembled kiosks which, after being fully equipped with electric light and telephone equipment, would be transported to the site and by the use of a rapid hardening cement be brought into service on the same day, whether the site was new or whether the kiosk was to be placed in the same position as one demolished.

This plan was developed in stages. Firstly, the fabric of new kiosks was painted unassembled in the paint shop and transported to the site, where it was erected and finished off with red putty. The Local Electricity Authority received the suggested method of change-over with avidity, and the initial experiment in the centre of Liverpool was an unqualified success. The old kiosk was demolished and the new one erected and brought into service in twelve hours—time being reckoned from leaving headquarters to returning. The staff employed was a three-man kiosk erection gang, installation fitter and E.L. & P. fitter.

The problem of transporting a completed kiosk has not been solved so rapidly. All the known methods of transportation possess some material disadvantage in that the manœuvrability or safety of the carrier leaves something to be desired. However, a device for lifting cable drums was seen at a local factory and the general principles of its design were put to the mechanics' shop. The mechanics immediately got busy on improving this design and two suggestions were submitted, one of which adopted a form of eccentric loading and shows great promise of ultimate success. The device involves the use of stub axles supporting a trailer framework. The loading platform for the kiosk is L-shaped, the base of the L supporting the base of the kiosk, and the vertical supporting the side of the kiosk. This platform is hinged near the centre of the vertical at the centre of gravity of the combined load, and the hinge is supported by an inverted carriage spring with shackles fixed to the trailer chassis. With the trailer in the horizontal position, the hinge is vertically in line with the stub axles. Lifting the arm of the trailer at the forward end moves the hinge in an arc relative to the axle and so lowers the L-platform



THE KIOSK CARRIER.

about three inches. Restoring the trailer arm to normal thus lifts the platform three inches. If the kiosk is erected on battens, the platform can be pushed under the base and the kiosk lifted for transportation. During transportation, the kiosk is carried at an angle of about 30° to the horizontal with the L-platform locked in that position. Placing the completed kiosk on site should then present little difficulty as the process of loading is simply reversed, and the kiosk can be set down on the foundation bricks prior to cementing.

The trailer has now been completed and preliminary trials on a few kiosks have shown that with an adequate kiosk programme a considerable saving of labour will result. W. F. D.

Junior Section Notes

Bath Centre

On the 12th January, 1950, a Junior Centre was formed in Bath, to cover, Bath, Chippenham and Wells Maintenance Areas. The membership reached the 30 mark immediately and is expected to be higher as the Centre becomes better known. Especially we should like support from the Chippenham, Q.Q.C.C. and Q.S.W.C. staffs.

The officers and committee appointed are :—

Chairman : S. A. R. Packer ; *Vice-Chairman :* A. L. Mainstone ; *Secretary :* G. A. E. Buckley ; *Treasurer :* K. H. Wonson ; *Committee :* J. Spicer, W. Read, J. E. Hawker, J. Vranch, R. E. Otridge.

The Committee hope to arrange monthly meetings and visits to places of scientific interest, and to this end contact has been established with a number of firms and individuals in the district.

Your support will make the work of the Committee easier and ensure a varied and interesting programme. All interested should contact a member of the Committee for full details of the Centre's activities. G. A. E. B.

Bradford Centre

The 1949-50 session opened on the 11th October, 1949, and a survey of the events up to the end of that month has already appeared in the Journal.

On the 15th November, Mr. G. Woodhead read an excellent paper on " Town and Country Planning," which was followed by a lively discussion. The paper was illustrated by lantern slides devised by Mr. Woodhead, and much information about a subject which concerns us all was imparted.

The 17th November, 1949, was the occasion of a Film Show and " Demonstration of a Model Locomotive," built by Mr. J. K. Scarth of the Bradford Model Engineers' Society. Mr. Scarth was assisted in the lecture and demonstration by Mr. C. Thornton, also of the B.M.E. Society. This was one of the most interesting and enjoyable meetings of the session.

On the 15th December a talk and demonstration on " Amateur Radio as a Hobby " were presented by the Bradford Telephone Area Sports and Social Club, Radio Section. This again was a very noteworthy meeting.

On 21st November, visits were made to the Bradford City Police " 999 " and Radio Central Station. All who attended agreed that " crime does not pay."

A milestone in the Centre's march of progress was reached on the 27th January, 1950, for this was the occasion on which we managed to defeat a very gallant team at Scarborough in a " Quiz Competition " conducted in our respective meeting places over amplified lines. The score was Bradford 31, Scarborough 27 ; this was really a big surprise to us as we had been given to understand that Scarborough were invincible, but perhaps the fact that, departing from usual procedure, we held this meeting in " The Market Tavern " and had fortified ourselves with sandwiches, etc., had an effect on our team ! A very enjoyable evening was spent both by us and Scarborough, and a return match will certainly be one of the attractions of next session's programme. Our thanks are extended to Scarborough for issuing the challenge and for co-operating to give us a jolly evening. Several senior members, including Mr. J. W. Barratt, the Regional Liaison Officer, and the Telephone Managers of Bradford and York came along and joined in the fun. All agreed that Departmental life and terms can have amusing sides even though we are apt to overlook them sometimes. These contests are recommended to other Centres, and Bradford is willing to challenge any other N.E. Region Centre.

At the time of writing these notes the programme for the remainder of the session was as follows :—

14th February, 1950.—Radio Control for Model Aircraft—Messrs. W. D. Priestly & H. T. Delaney.

16th March, 1950.—The Area Contract as Applied to the Erection of Cabinets and Pillars—Mr. A. Entwistle.

30th April, 1950.—Mechanical Aids—Mr. J. Peace.

31st May, 1950.—Annual General Meeting.

Suggestions for further visits and offers of short papers or talks will be welcomed by the Committee and will assist greatly in planning next year's programme.

A. E.

Brighton Centre

The following are the officers for 1949-50 :—

Chairman : K. W. Chandler ; *Vice-Chairman :* F. G. Anderson ; *Secretary :* R. F. J. Beddis ; *Librarian :* C. James ; *Committee :* Messrs. Beckett, Hulse, Mahood, Moore, Pitt, Pope, Kochelle, Trist.

Three meetings have been held, which have all been satisfactorily attended. Mr. H. M. Wells gave a lecture on picture telegraphy with excellent demonstrations of the apparatus used. Colonel C. E. Calveley's talk on " Staff " produced a very good discussion and Mr. F. T. Carwin, a local member, gave an excellent outline of Local Line Planning.

The remainder of the programme was :—

4th January.—After 25 Years—B. C. A. Stone.

1st February.—Modern Developments in Local Line Planning—R. M. Richards.

1st March.—Future Development in our Area—F. N. Charles.

The Annual General Meeting and Chairman's Address will be on 5th April, 1950.

Cambridge Centre

The centre was revived at a meeting held on 30th December, 1949, and the following officers were elected :—

Chairman : L. A. Salmon ; *Vice-Chairman :* H. W. Haworth ; *Secretary :* J. P. Wearn ; *Treasurer :* B. S. Cranfield ; *Committee :* L. R. Andrews, J. S. Manning, F. J. Davies.

The programme for the opening session was as follows :—Lecture : " Astronomy," by R. C. T. Warboys ; Visits to University Observatories and to University Elec. Eng. Lab.

The Annual General Meeting, with Film Show, will be held in May, 1950.

Chichester Centre

The officers are as follows :—

Chairman : W. C. Jackson ; *Vice-Chairman :* B. G. Ifould ; *Secretary :* R. W. Smith ; *Treasurer :* A. T. Yardley.

The membership is good considering our very scattered area and meetings have been interesting with good discussions. We have had papers on " I.C. Engines," by K. B. Salmon ; " Progress of the Telephone," by Mr. Carr ; " Clocks, Mechanical and Electrical," by N. L. Fletcher ; " Radio Interference," by N. Churcher ; and we are looking forward to a visit to the National Physical Laboratory.

Darlington Centre

Programme arrangements for the 1949-50 session were completed without difficulty and no excuses were offered by the Committee in submitting the following:—

11th October, 1949.—Carrier, Without Tears—Mr. G. B. Hart, A.M.I.E.E.

8th November, 1949.—Introduction to Atomic Energy—Mr. A. J. Shiell, B.Sc.

13th December, 1949.—U.A.X.s Simplified—Mr. G. Dale.

10th January, 1950.—Development and Planning—Messrs. R. V. Heppinstall and J. W. Brown.

7th February, 1950.—Amateur Radio—Mr. R. Dodds.

7th March, 1950.—The North-Eastern Electricity Board—Mr. T. E. Daniels, M.Eng., M.I.E.E., M.I.Mech.E.

18th April, 1950.—Annual General Meeting.

Expressions of appreciation of the talks given to date—by members and visitors—have been most encouraging to the Committee.

Visits to various works, etc., have also proved to be very popular.

On 9th November, 1949, the Centre arranged for parties to visit three collieries in the district and full advantage was taken by members, and visitors who attend monthly meetings, to whom we extended invitations.

Suitably garbed for the occasion they were conducted into the bowels of the earth and all the hazards of a miner's life below were brought home to them—in fact, one party, including the Area Engineer (Mr. A. C. Pitcairn) had to crawl on all fours through a 2-ft. seam to the coal face. A modern acquisition—the electrical coal cutter—was seen in operation, as also were other devices used in this underground industry. The experience created a profound impression and a higher respect for another man's job—coal mining.

The Darlington Power Station was the next port of call.

Congratulations to Middlesbrough Centre in arranging a visit from our President (Mr. H. R. Harbottle) on 16th February, 1950.

It is regretted that he will be unable to visit the Darlington Centre, too, but it is hoped that a representative number of members will be in attendance, and that it will be as successful as when our previous President (Mr. D. Smith) came to Darlington to mark the first visit of the President to a Provincial Junior Centre.

The recent suggestion to set up a " Junior Section Forum " in the *I.P.O.E.E.* Journal is welcomed, and it is thought that such a departure would lead to an exchange of views by various Centres to the common good of the Junior Section.

The Darlington Centre would like to read in this " Forum " the opinions of other centres as to how they think recognition could be given to a member who gives a talk without a paper—to enable him to participate in the competition sponsored by the Council of the Parent Institution. How could he be assessed and by whom ? If this could be decided then the Council could be approached to amend the rules which only allow a paper prepared in advance and read at a meeting to qualify.

The opinion of our Committee, in the light of experience, is that greater credit is due to a member who can say his piece without the written paper.

C. V. H.

Doncaster Centre

On lst December a trans-area quiz was held between Lincoln and Doncaster Centres. A 4-wire circuit was used, terminated at each end by microphones and loudspeakers.

Doncaster made off to an excellent start but at the end of the second half Lincoln had drawn equal. Both teams expressed a desire to play on in the hope of reaching a decision, but after two extended periods the scores were still equal. The match was, therefore, drawn.

It is hoped that the winners of the replay will compete for the Area Championship against the winners of the forthcoming Grimsby v. Scunthorpe quiz.

Mr. J. W. Barratt, A.M.I.E.E., was umpire, and question-masters were Mr. J. Willmot (Doncaster) and Miss Wall (Lincoln).

Teams were, Lincoln : Messrs. R. Found, T. Mullins, L. Reames, L. Burkilt, E. Smith and W. Barnes; Doncaster : Messrs. C. Gaunt, J. Barber, L. Hayes, K. Grainger, D. Perkins and J. I. Lawson. J. I. L.

Dundee Centre

The first meeting of the 1949-50 session was held on the 8th November in the Conference Hall, Telephone House, Mr. J. Knox, M.Sc., A.M.I.E.E., Area Engineer, giving an interesting and informative lecture, the subject being " The Shape of Things to Come."

At the close of the lecture the Annual General Meeting took place, and the following office-bearers were elected:—

Chairman : A. C. Gow ; *Vice-Chairman :* W. G. Craig ; *Secretary :* D. MacTaggart ; *Treasurer :* J. Lettice ; *Committee :* D. D. Watson, J. O. Pavey, K. K. Summers, J. A. Lamb and W. T. McCall.

At our last meeting, Mr. D. B. Wright, of Messrs. Larg & Sons (Dundee), Ltd., dealt with the subject of " Television " from its inception to present-day potentialities.

The remainder of the programme was as follows :—

17th January.—Dial 999—Mr. Gamble.

14th February.—Film Show.

14th March.—Quiz.

18th April.—Open Night and A.G.M.

It is pleasing to note that attendances have been good, and it is our intention to increase the interest of the staff in our activities. D. M.

Maidstone Centre

The following officers were elected at the Annual General Meeting :—

Chairman : G. T. Cheeseman ; *Secretary :* C. Tame ; *Treasurer :* R. W. Wallond ; *Committee :* Messrs. Barham, Borrows, Shaw, Garrod, Lager and Beckett.

The first meeting was a lecture on " Lens manufacture," followed by a visit to the Hanwell Optical Co. works where Mr. Johnson gave a fine insight into the practical side of lens manufacture. The next two meetings were on " Carrier Telephony Systems," by Mr. Regan, followed by Mr. Casey's paper on " Electrical Calculators."

The remainder of the programme comprised : " Main Line Planning," by F. C. Haliburton ; " Aircraft Engines " (Piston and Jet) ; and " Electricity Distribution," by E. G. Pope ; the Annual General Meeting will be held on 3rd April.

Middlesbrough Centre

It is pleasing to note that enthusiasm has been maintained, as shown in the increased attendances at the meetings.

17th November.—" Local Line Planning," by R. V. Heppinstall proved to be a most enjoyable lecture. An introduction by Mr. C. R. Harrison covering the aspect of Sales Division, hitherto an unknown quantity to many

of our members, was a most interesting approach to the subject.

15th December.—" Notes on Sound Reproduction," by Mr. H. C. Naylor, A.M.I.E.E. He gave demonstrations which included performance of gramophone pick-ups on test and ordinary records, and the reproduction of sound—with and without frequency restrictions—in a loudspeaker and on an oscilloscope.

19th January.—The lecture on Television, to be given by Mr. B. V. Northall, was postponed until a later date, due to an unfortunate accident involving Mr. Northall. We were fortunate, however, in obtaining the services of Mr. R. Dodds who, at short notice, offered to lecture on " Radar."

By the time these notes are in print we will have had our President (Mr. H. R. Harbottle) at one of our meetings, 16th February, 1950, to give us a lecture on " The Main Phenomena of Hearing and Their Bearing on the Design of Telephone Communication Systems." We greatly appreciate his help and interest in us and also the assistance given by our Liaison Officer (Mr. J. S. Gill) in making such a lecture available to us.

In a recent circular issued by the Secretary of the Senior Section it was suggested that the publicity of the Junior Section in the Journal could, with advantage, take the form of a Junior Section Forum. In the October, 1949, issue of the Journal, Mr. Harbottle in his article outlined the Junior Section's past achievements and future responsibilities. It is not much use dwelling in the past so then what of the future ? How are we going to get that desired lively interest and make full use of the opportunities available to us ? Plenty will discuss a football match or even an orchestral concert, but not so many are to be found to discuss in the right place—Junior Centre meetings—telecommunications and allied subjects. At a local technical college " Prize Day " one speaker took up the theme of training on the lines of the following :—

1. Character—Human relations.
2. Skill, resulting in pride of one's work and loyalty to one's employer.
3. Technology.
4. General education—learn as much as you can about as much as you can.

May it be suggested that we assist in all the four points but by informal means. Whilst Mr. Harbottle emphasises the " Local Centre" aspect of discussions, and we heartily agree, perhaps interest could be created on a " National " basis. As will have been observed in the Journal, we have given information of the activities of our Centre. This may have been of some help to less flourishing centres. We enjoy and look forward to the reading of activities of other centres. The Board of Editors of the Journal has promised us space so long as a regular supply of material is submitted. Why don't we all take advantage of this opportunity ? We would be pleased to correspond direct with other centres on a number of suggestions which we have in mind. We all work for the same firm and have common interests, so why don't we get to know one another a bit more? Not all of us go on training courses. We could discuss each other's problems and let each other know the results of our deliberations. Great fun as well as educational benefit is seen in the idea. May we hear from other centres either through the medium of the Journal or direct to J. Brown, c/o Telephone Manager's Office (Room 100), Marton Road, Middlesbrough.

J. B.

Portsmouth Centre

The following officers were elected at the Annual General Meeting :—

Chairman : V. Trowbridge ; *Vice-Chairman :* F. Warner ; *Treasurer :* E. D. Koughan ; *Secretary :* W. Forward.

An attractive programme was arranged for the second half of the session as follows : Lecture at St. Mary's Hospital on the apparatus associated with mass-radiography ; Visit to Pirelli-General Cable Works ; Lecture on " Electronics in Modern Industry," by W. Bacon and a conducted visit to H.P.O. Auto-Exchange and Repeater Station.

The concluding meetings are : 11th April, Films ; and 26th April, Annual General Meeting.

Scarborough Centre

The Annual Dinner Concert was held on Friday, 9th December, 1949, and a splended evening was enjoyed by all present.

Among the many senior members who attended were the Regional Director, Mr. L. G. Semple, and the Telephone Manager, Mr. H. A. Clibbon, who both made short speeches which were humorous, instructive and well appreciated. After an excellent dinner, the concert started and the fun was fast and continuous. Eighty-five members and friends attended and the Centre Officers and Committee wish to thank all who contributed to the success of the evening, including the guests who so kindly accepted our invitation and helped us in no small way to make a success of our " Annual."

On Friday, 27th January, 1950, the first inter-Area quiz competition was staged against Bradford. The Telephone Manager, Mr. H. A. Clibbon, broadcast to Bradford and extended greetings, and amongst other interesting remarks touched upon the work that had obviously been done beforehand by both Areas in connection with the evening's entertainment, and said that the event could well be described as a " Joint Production." Mr. H. S. M. Hall, the Telephone Manager, Bradford, responded suitably and the quiz was on.

The competition was eventually won by Bradford, who were worthy winners by a small margin. The evening's entertainment was finally ended at approximately 10 p.m. with Bradford extending a return date to Scarborough, which was promptly accepted. It was pleasing to see so many Senior members present, and in conclusion may we ask if there are any other Branches or Areas in the Region that would care to accept our friendly challenge to a quiz competition ? If so, Scarborough is waiting.

Come on the Junior Section ! A. B. C.

Tunbridge Wells Centre

The centre has been revived with the following officers :—

Chairman : A. E. Chapman ; *Secretary :* E. L. English ; *Treasurer :* J. P. Lawrence ; *Committee :* Messrs. Kingswood, Hasted, Waddell, Shoebridge, Johnson and Edwards.

The programme for the session covered " Trunk Telecommunications in India," by G. M. Blair ; a Visit to Fulham Power Station ; " Introduction to Coaxial Transmission," by G. F. Arnold and A. Peters and a " Scientific Quiz." The session concluded with a visit to Mount Pleasant Sorting Office.

Staff Changes

Promotions

Name	Region	Date
Area Engr. to Asst. Staff Engr.		
Couch, P. R.	N.E. Reg. to E.-in-C.O.	22.1.50
Ward, W. C.	Mid. Reg. to E.-in-C.O.	26.2.50
Area Engr. to Tel. Man.		
Mayne, E. A.	Stoke	1.12.49
Engr. to Area Engr.		
Palk, E.	L.T. Reg.	4.1.50
Prob. Engr. to Engr.		
Bastow, F. J.	E.-in-C.O.	17.11.49
Bishop, D. K.	E.-in-C.O.	7.11.49
Bourne, K. W.	E.-in-C.O.	8.11.49
Finnamore, A. J.	E.-in-C.O.	5.11.49
Hughes, H. S.	E.-in-C.O.	13.11.49
Lewis, T. A.	E.-in-C.O.	2.11.49
Wray, D.	E.-in-C.O.	5.11.49
Wade, C. D.	Scot.	24.11.49
Partridge, J. G.	E.-in-C.O.	1.12.49
Tod, D. S.	E.-in-C.O.	1.12.49
Harris, L. R. F.	E.-in-C.O.	1.12.49
Baily, N. G.	E.-in-C.O.	8.12.49
Clinch, C. E. E.	E.-in-C.O.	1.12.49
Davidson, C. F.	E.-in-C.O.	1.12.49
Forster, A. E. T.	E.-in-C.O.	9.12.49
Cobbe, D. W. R.	E.-in-C.O.	1.12.49
Prob. Engr. to Engr.—continued		
Horsfield, B. R.	E.-in-C.O.	1.12.49
Tattersall, R. L. O.	E.-in-C.O.	1.12.49
Froom, R. P.	E.-in-C.O.	1.12.49
Haworth, J. E.	E.-in-C.O.	1.12.49
May, C. A. M.	E.-in-C.O.	5.1.50
Hill, L. W.	E.-in-C.O.	5.1.50
Burton, R. N.	E.-in-C.O.	5.1.50
Hudson, G. K.	E.-in-C.O.	5.1.50
Vernon, D. H.	E.-in-C.O.	19.1.50
Asst. Engr. to Engr.		
House, L. F.	S.W. Reg.	3.1.50
Hutchings, W. S.	L.T. Reg.	7.1.50
Plant, F.	N.W. Reg.	21.1.50
Brown, W. D.	W.B.C. Reg. to L.T. Reg.	1.2.50
Fable, F. P.	H.C. Reg.	31.1.50
Bouquet, H. F.	E.-in-C.O.	3.1.50
Lamb, A. H.	N.E. Reg. to E.-in-C.O.	3.1.50
Batt, T. D.	H.C. Reg. to E.-in-C.O.	22.1.50
Coulman, A. H.	E.-in-C.O.	1.2.50
Tech. Off. to Asst. Engr.		
Petchey, R. F.	E.-in-C.O.	7.11.49
Springett, F.	E.-in-C.O.	7.11.49
Charlton, R. D.	E.-in-C.O.	9.1.50
Thraves, C. M.	E.-in-C.O.	23.1.50

Transfers

Name	Region	Date
Asst. Staff Engr.		
Edwards, J. J.	E.-in-C.O. to L.T. Reg.	26.2.50
Engr.		
Hinchcliffe, J. D.	E.-in-C.O. to Min. of Supply	1.12.49
Jemmeson, A. E.	Scot. to N.E. Reg.	1.1.50
Mayne, R. T.	E.-in-C.O. to N.E. Reg.	12.2.50
Lee, A.	E.-in-C.O. to Min. of Supply	15.6.49
Prob. Engr.		
Saunders, J. C.	S.W. Reg. to Nigeria (Seconded)	17.12.49
Burley, N.	E.-in-C.O. to N.E. Reg.	1.2.50
Asst. Engr.		
Whitaker, T. H.	E.-in-C.O. to N.E. Reg.	9.12.49
Connell, D. R. W.	E.-in-C.O. to S.W. Reg.	1.1.50
Martin, A. C.	E.-in-C.O. to Nigeria (Seconded)	21.12.49
Millson, H. W.	E.-in-C.O. to Australian P.O.	18.12.49
Asst. Engr.—continued		
Gerrard, H.	N.E. Reg. to E.-in-C.O.	2.1.50
Edwards, H. W. F.	E.-in-C.O. to Australian P.O.	12.1.50
Sims, G. H.	E.-in-C.O. to Australian P.O.	24.11.49
Wright, J. E.	E.-in-C.O. to N.E. Reg.	9.1.50
Butterworth, B. B.	E.-in-C.O. to P. & T. Dept. E. Africa (Previously seconded)	19.9.47
Knight, E. D.	N.E. Reg. to Colonial Service (Previously seconded)	5.4.46
McPherson, J. W.	L.T. Reg. to E.-in-C.O.	6.2.50
Gannon, J.	E.-in-C.O. to N.E. Reg.	13.2.50
Norman, J. M.	E.-in-C.O. to P.R.D.	18.1.50
Hope, S.	E.-in-C.O. to N.W. Reg.	27.2.50
Benford, H.	E.-in-C.O. to Mid. Reg.	1.12.49
Asst. (Scientific)		
Guy, J. A.	E.-in-C.O. to Foreign Office	1.2.50

Retirements

Name	Region	Date
Asst. Staff Engr.		
Morrish, H. E.	E.-in-C.O.	31.12.49
Area Engr.		
Gunston, J. A.	L.T. Reg.	31.12.49
Exec. Engr.		
Jacquest, A. H.	E.-in-C.O.	31.1.50
Engr.		
Humphreys, L. W.	L.T. Reg. (Resigned)	31.8.49
Green, F. C.	L.T. Reg.	31.12.49
Smith, J. G.	L.T. Reg.	31.1.50
Ferris, J. H.	E.-in-C.O. (Health grounds)	19.2.50
Asst. Engr.		
Sands, J. L.	Mid. Reg.	31.12.49
Andrews, H. H.	E.-in-C.O. (Health grounds)	3.12.49

Retirements—*continued*

Name	Region	Date
Asst. Engr.—continued		
McNeille, J. L.	L.T. Reg.	31.12.49
Boughey, S. H.	L.T. Reg.	31.12.49
Levens, T. F.	N.W. Reg.	31.12.49
Phipps, E. H.	Mid. Reg.	31.12.49
Taylor, G. W.	Mid. Reg.	31.12.49
Johnson, S. H.	Mid. Reg.	31.12.49
Kershaw, S.	N.E. Reg.	31.12.49
Frost, W.	Mid. Reg.	31.12.49
Prior, G.	E.-in-C.O.	31.12.49
Norfolk, E. W.	E.-in-C.O.	31.12.49
McNabb, J. B.	E.-in-C.O. (Resigned)	24.1.50
Beer, T.	W.B.C. Reg.	3.2.50
Goodwin, E. W.	W.B.C. Reg.	31.7.49
Barker, J.	L.T. Reg.	31.1.50
Kinsella, L. B.	L.T. Reg.	20.2.50
Jeffrey, E.	N.E. Reg.	31.3.49
Brierley, N.	E.-in-C.O.	18.2.50
Lamont, K.	E.-in-C.O. (Resigned)	28.2.50
Pease, T. B.	N.E. Reg.	27.2.50
Inspr.		
Isaacs, R.	Scot.	31.12.49
Rowland, H.	N.W. Reg.	22.2.50
Chambers, R. G.	W.B.C. Reg.	22.9.49
Inspr.—continued		
Parkinson, J. W.	N.E. Reg.	31.12.49
McArdle, T. A. D.	N.E. Reg. (Resigned)	31.9.49
Oliver, W.	N.I. Reg.	31.8.49
Heather, W. A.	L.T. Reg.	31.12.49
Roach, H. C.	S.W. Reg.	31.7.49
Groves, E. J.	S.W. Reg.	31.8.49
Hollerton, F.	N.W. Reg.	31.12.49
Moss, J. W.	N.W. Reg.	31.12.49
Andrews, H. E.	L.T. Reg.	18.2.50
Richards, C. A.	L.T. Reg.	31.12.49
Frood, B.	S.W. Reg. (Resigned)	31.12.49
Foster, A. T.	L.T. Reg.	20.8.49
Fox, R. R.	L.P. Reg.	23.10.49
Thatcher, A. C.	L.T. Reg.	18.12.49
Robertson, V. G. S.	Scot.	20.11.49
Asst. Exper. Off.		
Clarke, D. T.	E.-in-C.O. (Resigned)	31.12.49
Temp. Asst. Exper. Off.		
Gleed, K. E.	E.-in-C.O. (Resigned)	31.1.50
Asst. (Scientific)		
Harrison (Mrs.), M. M.	E.-in-C.O. (Resigned)	27.1.50

Deaths

Name	Region	Date
Asst. Engr.		
Cousens, A. J.	L.T. Reg.	12.12.49
Leyland, T.	N.W. Reg.	18.1.50
Armitage, H.	N.W. Reg.	17.1.50
Checkley, E. W.	Mid. Reg.	3.2.50
Asst. Engr.—continued		
Birkenshaw, T.	N.E. Reg.	4.2.50
Snowling, J. W.	E.-in-C.O.	13.2.50
Laing, D. M.	Mid. Reg.	17.2.50

CLERICAL GRADES

Promotions

Name	Region	Date
E.O. to H.E.O.		
Ridland, L.	E.-in-C.O.	1.1.50
Duncan, W. B.	E.-in-C.O.	1.1.50
C.O. to E.O.		
Gregory, H. I. (Miss)	E.-in-C.O.	1.1.50

Transfer

Name	Region	Date
H.E.O.		
Goodway, T. C.	E.-in-C.O. to Min. of Fuel and Power	3.2.50

Retirements

Name	Region	Date
H.E.O.		
Warden, J. G. H.	E.-in-C.O.	31.12.49
H.E.O.—continued		
Ost, H. J.	E.-in-C.O.	31.12.49

I.P.O.E.E.—(*Continued from page* 50)

Recent additions to the Institution Library include the following:—

1854 *Principles of Radar.* D. Taylor and C. H. Westcott (British 1948).

An exposition and survey of the principles underlying radar design, which indicates the common factors which underline the many types of radar equipment.

1855 *Technical Optics, Vol. I.* L. C. Martin (British 1948).

This volume deals with general matters, including a short introduction to the theory of spectacles, and is designed to awaken a living interest in the scientific aspects of the subject.

1858 *The Royal Signals Handbook of Line Communication, Vol. I.* (British 1947).

A comprehensive textbook dealing with the basic theory required for study of line communications and including a summary of the mathematics necessary for this. Reviewed in *P.O.E.E.J.*, Vol. 41, p. 233.

1862 *Refrigeration and Air Conditioning Guide.* E. P. Anderson (American 1948).

Prepared as a helpful service guide providing useful information covering all phases of modern mechanical refrigeration and air conditioning.

1865 *Elementary Telecommunications Practice.* W. T. Perkins (British 1948).

Covers the syllabus of the City and Guilds of London Institute examination. Reviewed in *P.O.E.E.J.*, Vol. 41, p. 227.

1866 *Mechanics and Applied Heat.* S. H. Moorfield and H. H. Winstanley (British 1948).

This book's object is to present in one volume a course in engineering science which will prepare a student for entry upon the final year of the Ordinary National Certificate Course.

1867 *Your Obedient Servant.* Institute of Public Administration (British 1948).

Being some reflections on correspondence between Government Departments and the Public.

1868 *Working Conditions in the Civil Service* (British 1947). A report by a Study Group set up by the Treasury in 1943 to consider how the efficiency of the Civil Service might be increased.

1869 *Technical Literature.* G. E. Williams (British 1948).

This handbook is addressed chiefly to engineers and physicists, to assist them in preparing technical and scientific papers. Reviewed in *P.O.E.E.J.*, Vol. 41, p. 221.

1870 *The Presentation of Technical Information.* R. O. Kapp (British 1948).

A guide to the art of exposition.

1871 *Telephony, Vol. I.* J. Atkinson (British 1948).

A detailed exposition of the Telephone Exchange Systems of the British Post Office—General Principles and Manual Exchange Systems. Reviewed in *P.O.E.E.J.*, Vol. 41, p. 212.

1875 *Mathematics for Technical Students.* A. Geary, H. V. Lowry and H. A. Hayden—Part III (British 1948).

This series is designed to provide the basic mathematical equipment for technical students. Part III covers the third year of the National Certificate Courses in Engineering, Building and Chemistry.

1876 *Micro-Waves and Wave Guides.* H. M. Barlow (British 1947).

A special effort has been made in this book to capture the attention and interest in this subject. It is essentially practical, and gives the kind of explanation that is most satisfying and acceptable to the widest possible circle of readers. Reviewed in *P.O.E.E.J.*, Vol. 42, p. 98.

W. D. FLORENCE, *Librarian*

BOARD OF EDITORS

H. FAULKNER, C.M.G., B.Sc., M.I.E.E., Chairman.
F. E. NANCARROW, O.B.E., A.R.C.Sc., M.I.E.E.
P. B. FROST, B.Sc., M.I.E.E.
A. H. MUMFORD, O.B.E., B.Sc.(ENG.), M.I.E.E.
W. T. GEMMELL, A.C.G.I., B.Sc., M.I.MECH.E., A.M.I.E.E.
W. WEST, B.A., M.I.E.E.
D. A. BARRON, M.Sc., A.M.I.E.E.
A. F. STOLLARD.
G. E. STYLES, A.M.I.E.E., Managing Editor.
W. A. HUMPHRIES, A.M.I.E.E.
J. P. HARDING, B.Sc.(ENG.), A.M.INST.C.E., A.M.I.E.E. } Assistant Editors.
A. J. HUTCHISON, Secretary-Treasurer.

Copyright

The entire contents of this JOURNAL are covered by general copyright, and special permission is necessary for reprinting long extracts, but Editors are welcome to use not more than one-third of any article, provided credit is given at the beginning or end thus: "From the *Post Office Electrical Engineers' Journal.*"

The Board of Editors is not responsible for the statements made or the opinions expressed in any of the articles in this JOURNAL, unless such statement is made specifically by the Board.

Communications

All communications should be addressed to the Managing Editor, *P.O.E.E. Journal*, Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Telephone: HEAdquarters 1234. Remittances should be made payable to "*The P.O.E.E. Journal*" and should be crossed "& Co."

Binding Cases

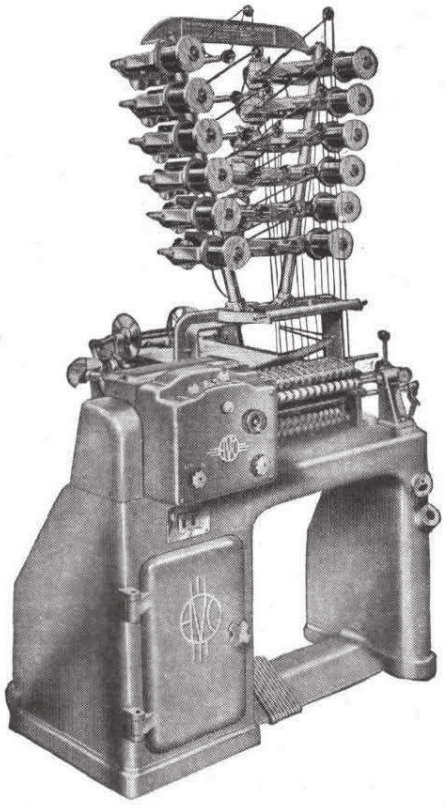
Cases for binding are available, and may be obtained from the Local Agents for 2s. Subscribers can have their copies of Volumes bound, at a cost of 7s. 6d., by sending the complete set of parts to the Local Agents or to the *P.O.E.E. Journal*, Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Orders for binding for Vols. 1-19 should indicate whether the original binding case with black lettering, or the later pattern with gold, is required. Cases with gold lettering are the only type stocked from Vol. 20 onwards.

Back Numbers

The price of the JOURNAL, which is published quarterly, is 1s. 6d. (1s. 9d. post free) per copy, or 7s. per annum post free. Back numbers can be supplied, subject to availability of stocks, at 1s. 6d. each (1s. 9d. post free). Orders for back numbers may be sent to the Local Agents or to the Publishers.

Advertisements

All communications relating to space reservations should be addressed to the Advertisement Editor, *P.O.E.E. Journal*, Alder House, Aldersgate Street, London, E.C.1. Communications regarding advertisement copy, proofs, etc., should be addressed to the Publishers, Messrs. Birch & Whittington (Prop. Dorling & Co. [Epsom], Ltd.), 49 Upper High Street, Epsom, Surrey.

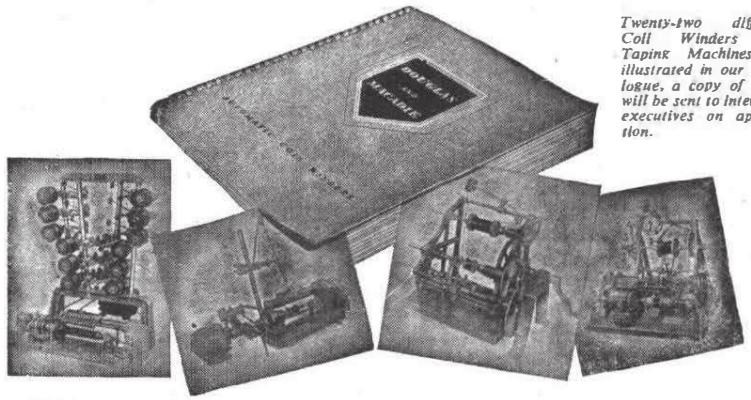


DOUGLAS AND MACADIE

Automatic

COIL WINDERS

The large illustration depicts the improved "Douglas" Fully Automatic Multi-Winder, specially developed for the high-speed production of large quantities of coils with or without paper interleaving. It will produce round, square or rectangular coils up to 6 in. each in length and up to 4½ in. diameter. As many as 12 smaller coils can be wound simultaneously within the total available winding length of 12 in. at headstock speeds of between 600 and 2,000 r.p.m.



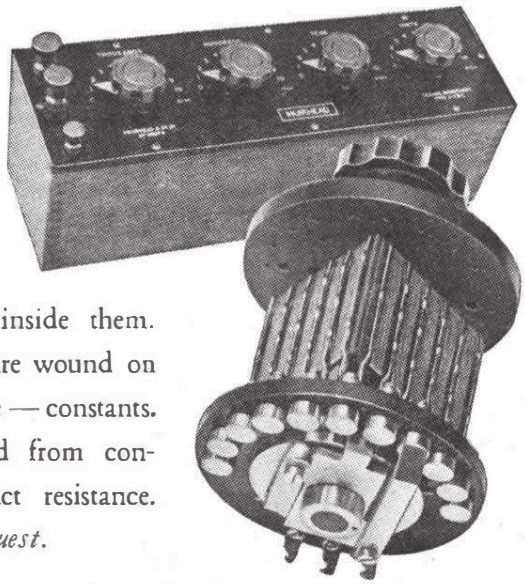
Twenty-two different Coil Winders and Taping Machines are illustrated in our Catalogue, a copy of which will be sent to interested executives on application.

Sole Proprietors and Manufacturers :

The AUTOMATIC COIL WINDER & ELECTRICAL EQUIPMENT CO. LTD.
WINDER HOUSE • DOUGLAS STREET • LONDON • S.W.1 *Telephone: VICTORIA 3404/9*

C.2

There's more in resistance work than meets the eye!



Many have remarked on the fine appearance of Muirhead Decade Resistance Boxes — but we are even more concerned with what we put inside them. Take, for instance, the A-25 series; all resistors are wound on cards by methods that ensure very low time — constants. The internally mounted switches are protected from contamination and have low and constant contact resistance.

Descriptive literature will be sent on request.

MUIRHEAD

Muirhead & Co. Limited, Elmers End, Beckenham, Kent. Tel. Beckenham 0041-2

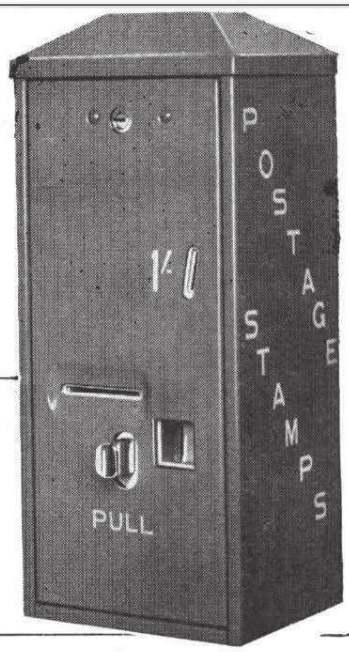
FOR OVER 60 YEARS DESIGNERS & MAKERS OF PRECISION INSTRUMENTS

CRC 67b

A Typical Example of

H.T.A. DESIGN

Stamp Booklet Vending machines to suit full size and half size booklets, for both indoor and outdoor application, are recent additions to the range of H.T.A. Products. These also include Telephone Coin Collectors, Stamp Selling Machines, Commodity Vending Machines, Ticket Printing and Issuing Machines, etc. etc.



STAMP BOOKLET VENDING MACHINE.

The model illustrated is suitable for both Indoor and Outdoor use. A smaller machine is available for Indoor use in Post Offices, for Bookstalls and for Hotels to give this service to customers. Both machines can be supplied for either base or wall fixing. The capacity is 120 booklets 1 m.m. thick ranging in sizes from 25 m.m. x 47 m.m. to 50 m.m. x 70 m.m.

Enquiries should include size or samples of booklets in use and the coins required to operate the mechanism.

HALL TELEPHONE ACCESSORIES LTD

Precision Engineers & Instrument Makers

DUDDEN HILL LANE • WILLESDEN • LONDON • N. W. 10

PHONE: WILLESDEN 5141

Here is ample proof of the reliability of Westinghouse Metal Rectifiers. This charger was installed in 1929 and has been working constantly ever since on a 110-volt supply.

The customers now require to use it on a 230-volt supply and the set has been sent in for a transformer rewind. The opportunity of testing the rectifiers and the rest of the components was taken, when it was found that everything was up to standard and the set was still giving its full rated output.

WESTINGHOUSE RECTIFIERS

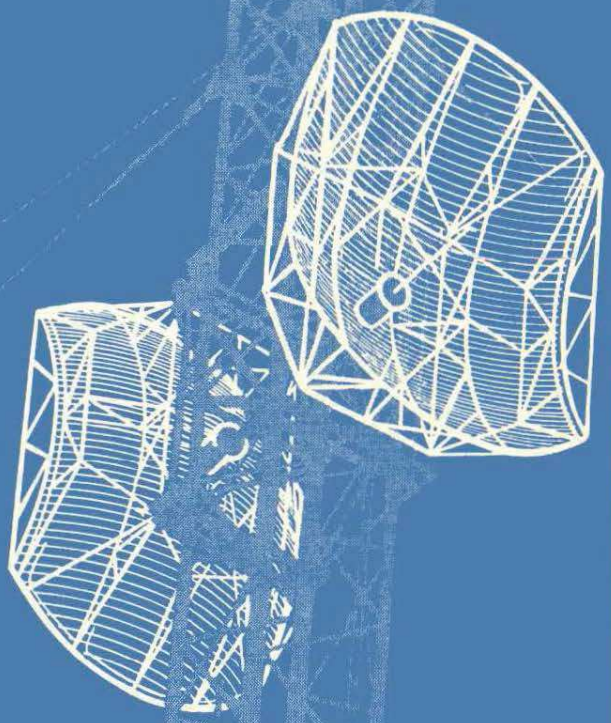
withstand the test of time

WESTINGHOUSE BRAKE & SIGNAL CO. LTD.
82 York Way, King's Cross, London, N.1

The resources of the G.E.C.

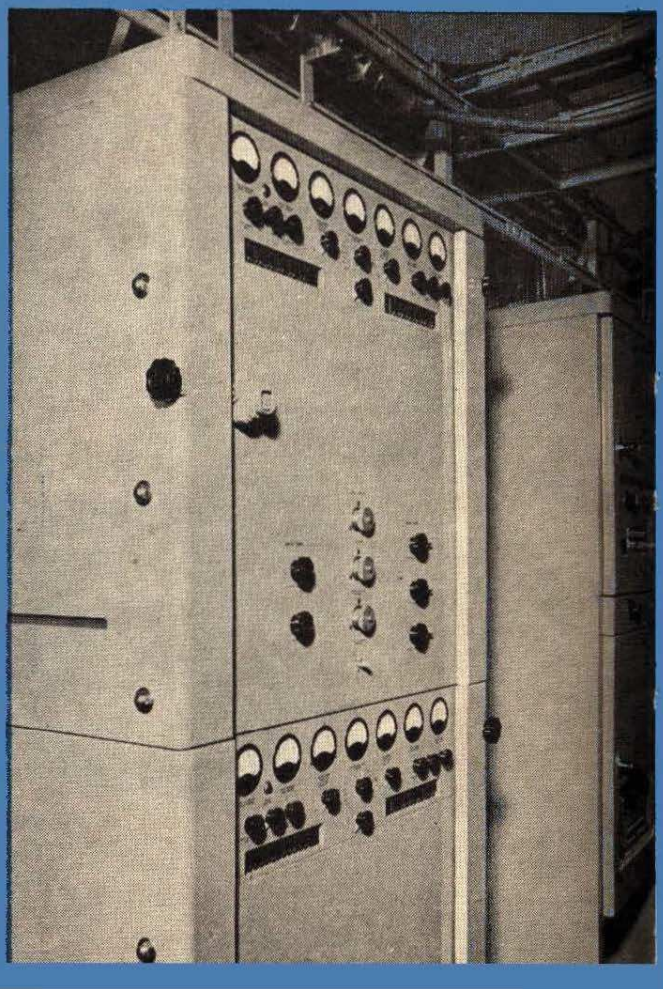
LONDON BIRMINGHAM

opened for daily service – 17th December 1949



The associated company, Pirelli-General Cable Works, designed the towers and the special feeder cables used within the equipment.

Exterior of transmitter cabinets, showing alternative transmitters

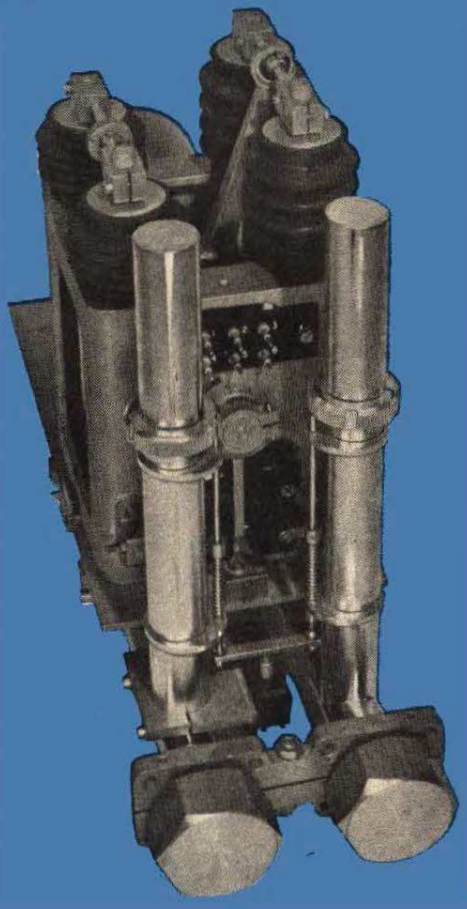


were behind the development of the

TELEVISION LINK

The resources of The General Electric Company were behind the design, production, installation, testing and servicing of the London-Birmingham television link. All that could be contrived for wideband U.H.F. transmission by knowledge, ingenuity and skill, in the Research Laboratories at Wembley and the Telephone Works at Coventry, went into the link. Now, after the link has been working for weeks of daily scheduled service, the G.E.C. has reaped the dividend in practical experience of its ideas on propagation, the processes of modulation, demodulation and frequency changing for a relayed U.H.F. system, automatic and almost instantaneous changeover to standby equipment, reversals of direction of transmission, and remote control from the terminals.

Equipment for phase 2, to give simultaneous bothway transmission, is now in production.



A radio-frequency contactless aerial switch.

For everything in telecommunications consult:—

THE GENERAL ELECTRIC COMPANY LTD. OF ENGLAND

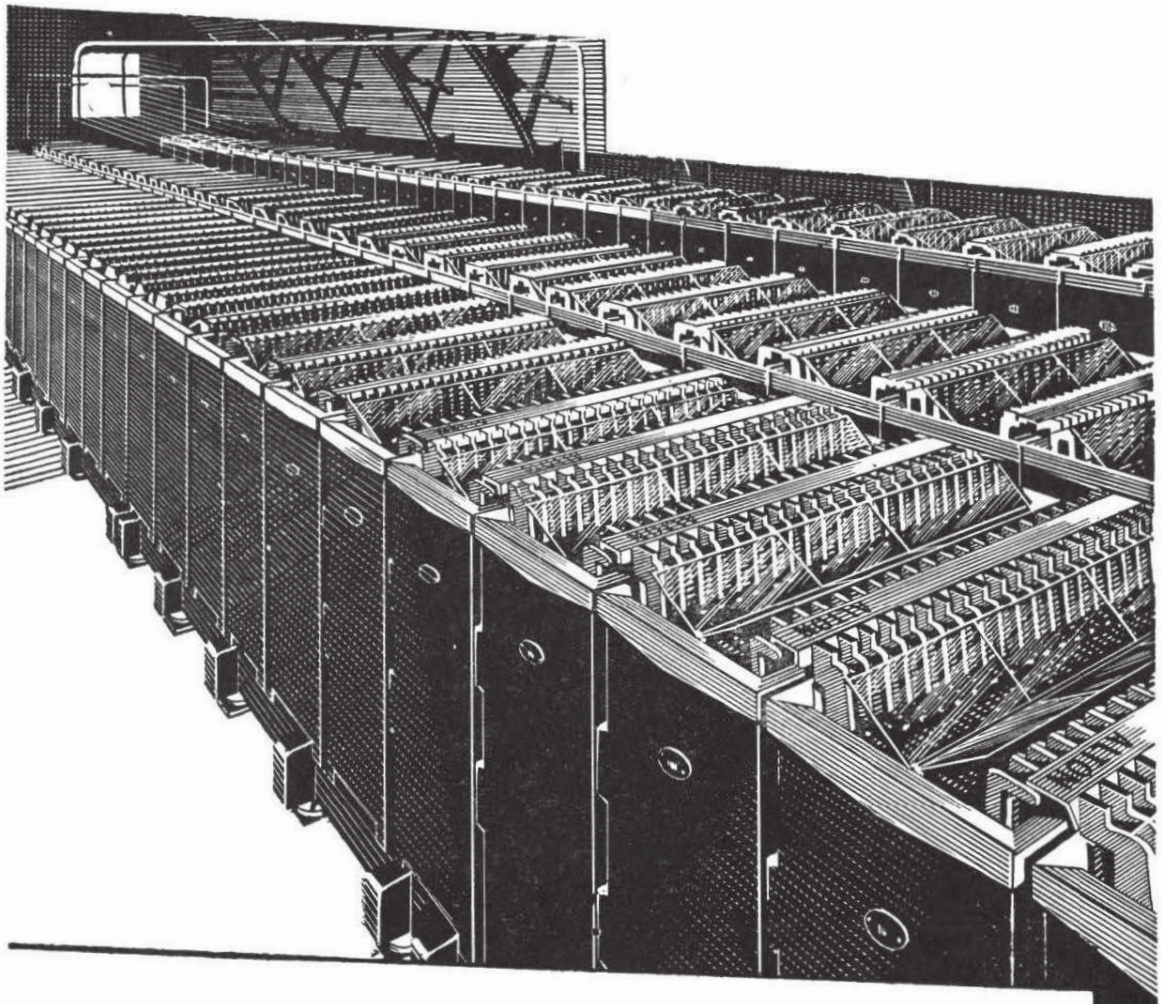
TELEPHONE, RADIO AND TELEVISION WORKS . COVENTRY . ENGLAND

Telephone: Coventry 4111 (10 lines) *Telegrams and Cables: "Springjack, Coventry"*

The largest British electrical manufacturing organisation in the world

HEAD OFFICE · MAGNET HOUSE · KINGSWAY · LONDON · W.C. 2

Temple Bar 8000 (90 lines) *"Electricity, Westcent, London"* *Cables: "Polyphase, London"*



Alton Batteries of 10 to 15,000 ampere-hours are in service in sixty-five countries. The batteries now being shipped out all over the world will carry the name of Alton still further afield—Alton, shortest word in any language for good batteries and firm delivery dates.

*

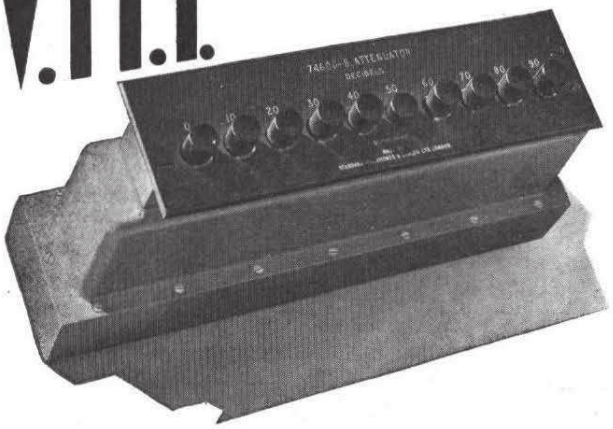
Alton can also supply renewal plates for all makes of battery, British and Continental.

ALTON

BATTERIES OF MERIT

THE ALTON BATTERY COMPANY LIMITED, Alton, Hampshire · Telephone: Alton 2267 and 2268 · Telegrams: Battery, Alton

V.H.F PUSH BUTTON ATTENUATOR



True V.H.F. loss measurement at last!

An outstanding development which in the first year of production has fully established itself with leading British communication organisations and remains the first and only accurate instrument of its kind.

Two models available

Type 74600 - A : 0 - 9 db in 1 db steps

Type 74600 - B : 0 - 90 db in 10 db steps

Both have a 75 - ohm characteristic impedance and will handle inputs up to 0.25 watts.

50 *Mc/s Performance* *

MODEL	VARIATION BETWEEN 50 Mc/s and D.C.	ACCURACY OF D.C. ADJUSTMENT
0 - 9 db	<± 0.01 db per step	± 0.05 db at all settings
0 - 90 db	<± 0.1 db per step	± 0.03 db per step

** Insertion loss relative to zero setting*

Ready for building into your own equipment

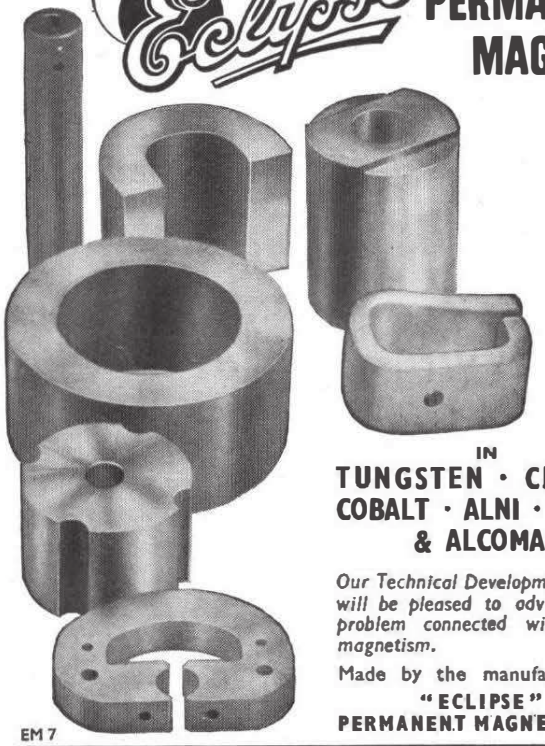
Calibration charts for frequencies up to 100 Mc/s for the 0 - 9 db model or 60 Mc/s for the 0 - 90 db model can be supplied on request.

Standard Telephones and Cables Limited

Registered Office : Connaught House, Aldwych, London, W.C.2

TRANSMISSION DIVISION, NORTH WOOLWICH, LONDON, E.16

Eclipse **PERMANENT MAGNETS**



IN TUNGSTEN · CHROME COBALT · ALNI · ALNICO & ALCOMAX

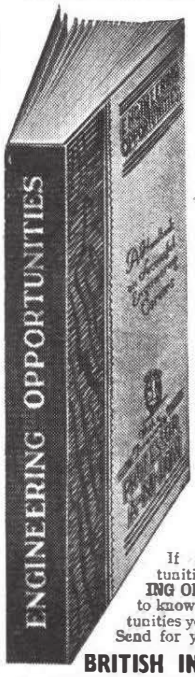
Our Technical Development Section will be pleased to advise on any problem connected with applied magnetism.

Made by the manufacturers of **"ECLIPSE" PERMANENT MAGNET CHUCKS**

EM 7

JAMES NEILL & CO. (Sheffield) LTD., SHEFFIELD, ENGLAND

VALUABLE FREE BOOK



Tells You How to Pass Your C. & G. or Promotion Exam. at *First* Attempt!

All Post Office Engineering personnel who are anxious to obtain early pro otion should at once send for a copy of our handbook **"ENGINEERING OPPORTUNITIES,"** which, a ong other intensely interesting matter, describes our unique methods of preparation for **TECHNICAL APPOINTMENTS IN THE POST OFFICE** (Assistant Engineer—New Style and Assistant Traffic Superintendent), **A.M.I.E.E., CITY AND GUILDS EXAMINATIONS** in Principles of Telecommunications (1-5), Radio (1-4), Telephone Exchange Systems (1-3), Telegraphy (1 and 2), Line Transmission (1 and 2), Lines Plant Practice (1 and 2), Mathematics for Telecommunications (1-5), Electrical Engineering Practice (Prelim. Inter. and Final), and outlines a wide range of non-examination courses in all branches of **Electrical, Mechanical, Civil, Automobile, Aeronautical and Radio Engineering.**

Assistant Engineer and Assistant Traffic Superintendent. Open competitions now resumed. Age extensions for established Civil Servants. Ask us for full details

We definitely guarantee "NO PASS—NO FEE"

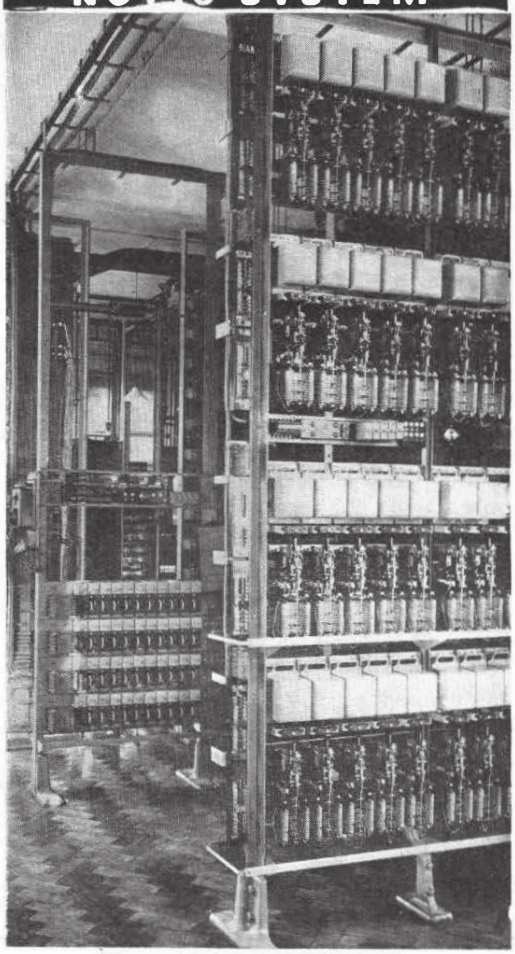
If ou intend to make the most of to-day's opportunities, you cannot afford to miss reading **"ENGINEERING OPPORTUNITIES."** It tells ou everything ou want to know to secure advancement, and describes many opportunities you may now be missing through lack of information. Send for your copy to-day—**FREE** and without obligation.

BRITISH INSTITUTE OF ENGINEERING TECHNOLOGY
369 SHAKESPEARE HOUSE, 17-19 STRATFORD PLACE, LONDON, W.1

BIET

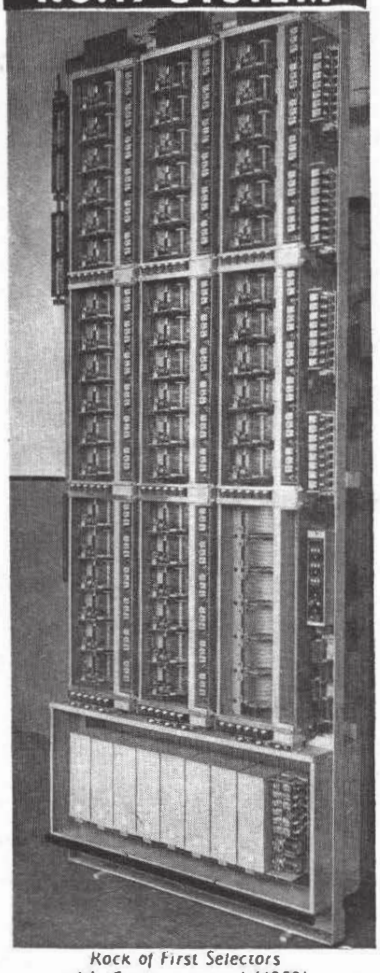
SIEMENS *Automatic* TELEPHONE EXCHANGES

NO. 16 SYSTEM



Automatic Racks Preston Exchange, Brighton (1927)

NO. 17 SYSTEM



Rack of First Selectors with Covers removed (1950)

PRESTON (BRIGHTON) T.E.

Preston automatic exchange (Siemens 16, installed in 1927) is a satellite on Brighton with 5,200 working lines. Over the past year, the reported exchange faults have averaged about 0·04 faults per telephone per annum. During each of the weeks ending 2nd and 23rd September, 1949, the exchange excelled itself and the number of reported exchange faults was nil. Is this a record ?

D. C. B.

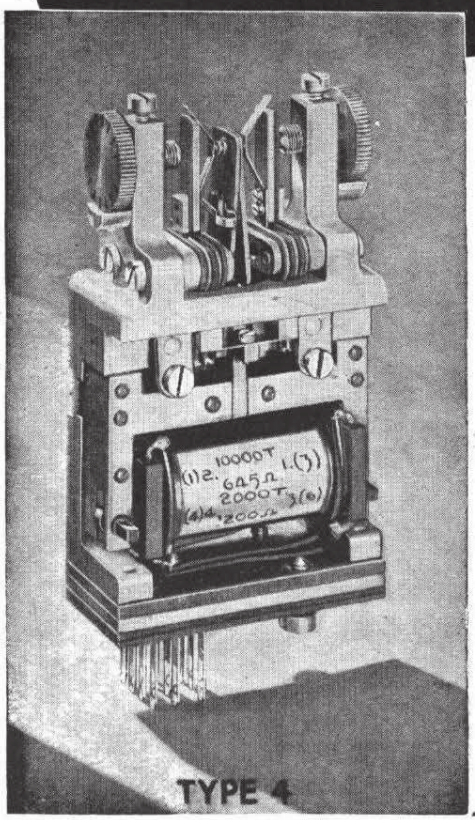
Extract from Post Office Electrical Engineers' Journal, Jan. 1950 p.237

As in 1927, reliability is still a primary aim, and achievement, of our switching systems

SIEMENS BROTHERS & CO., LIMITED

WOOLWICH · LONDON · S.E.18.

CARPENTER Polarized RELAY
TYPE 4



This is a medium speed, sensitive relay with long contact travel designed primarily as a telephone impulsing relay (D.C. dialling up to 100 miles and V.F. dialling on trunk circuits). It has also been successfully adopted for use in Telex systems.

Its sensitivity is such that when the gap is adjusted to .004 in. the relay will just operate at 50 cycles with 4 ampere-turns (corresponding to approximately 1 mVA) or on 2½ D.C. ampere-turns at low speeds. In service, however, the relay is normally operated at currents substantially larger than the minimum operating current.

Contact chatter is absent if the contact gap does not exceed .004 in. The contact gap is adjustable by means of fine pitch screws with knurled heads marked with .001 in. divisions.

Contacts on the armature tongue are insulated from it and thereby from the frame.

Terminals for soldered connections are fitted as standard.

The relay is supplied with a magnetic screening cover with transparent removable top to facilitate contact adjustment.

Dimensionally the relay is interchangeable with the type "3000" relay and can be supplied to fit directly to the drilling normally provided for the "3000" relay.

Dimensions of the Type 4 Carpenter Relay are:— (With cover. Excluding wiring tags) 3 3/16 ins. high × 2 3/16 ins. wide × 1 in. deep. Weight: 13 ozs.

Complete details available on request. *Manufactured by the Sole Licencees:—*

TELEPHONE MANUFACTURING CO. LTD.

Contractors to the British Commonwealth and Foreign Governments

HOLLINGSWORTH WORKS DULWICH LONDON, S.E.21

Telephone: GIPsy Hill 2211 (10 lines)

HIGH GRADE

DECADE ATTENUATORS

0·1% GRADE

T or H NETWORKS

RANGE 0·1 to 110 db.
0·01 to 10 nepers

TEMP. COEFF.
0·0025% C

NO ERRORS UP TO FREQUENCIES OF 100 Kc/s AND EXTREMELY USEFUL FOR FREQUENCIES UP TO 0.5 OR 1 Mc/s

ASSEMBLED INTO A DECADE SERIES OR AS PANEL MOULDED UNITS

ALSO SUPPLIED IN PORTABLE CARRYING CASES, COMPLYING WITH LINE TESTING REQUIREMENTS OF THE BRITISH POST OFFICE

H. W. SULLIVAN

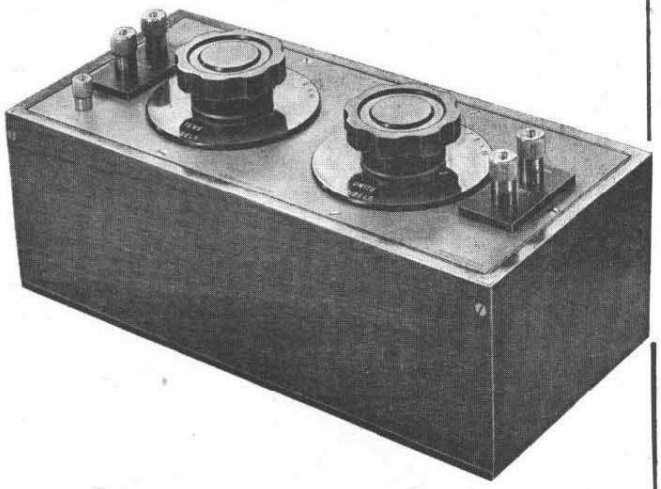
— LIMITED —

LONDON, S.E.15

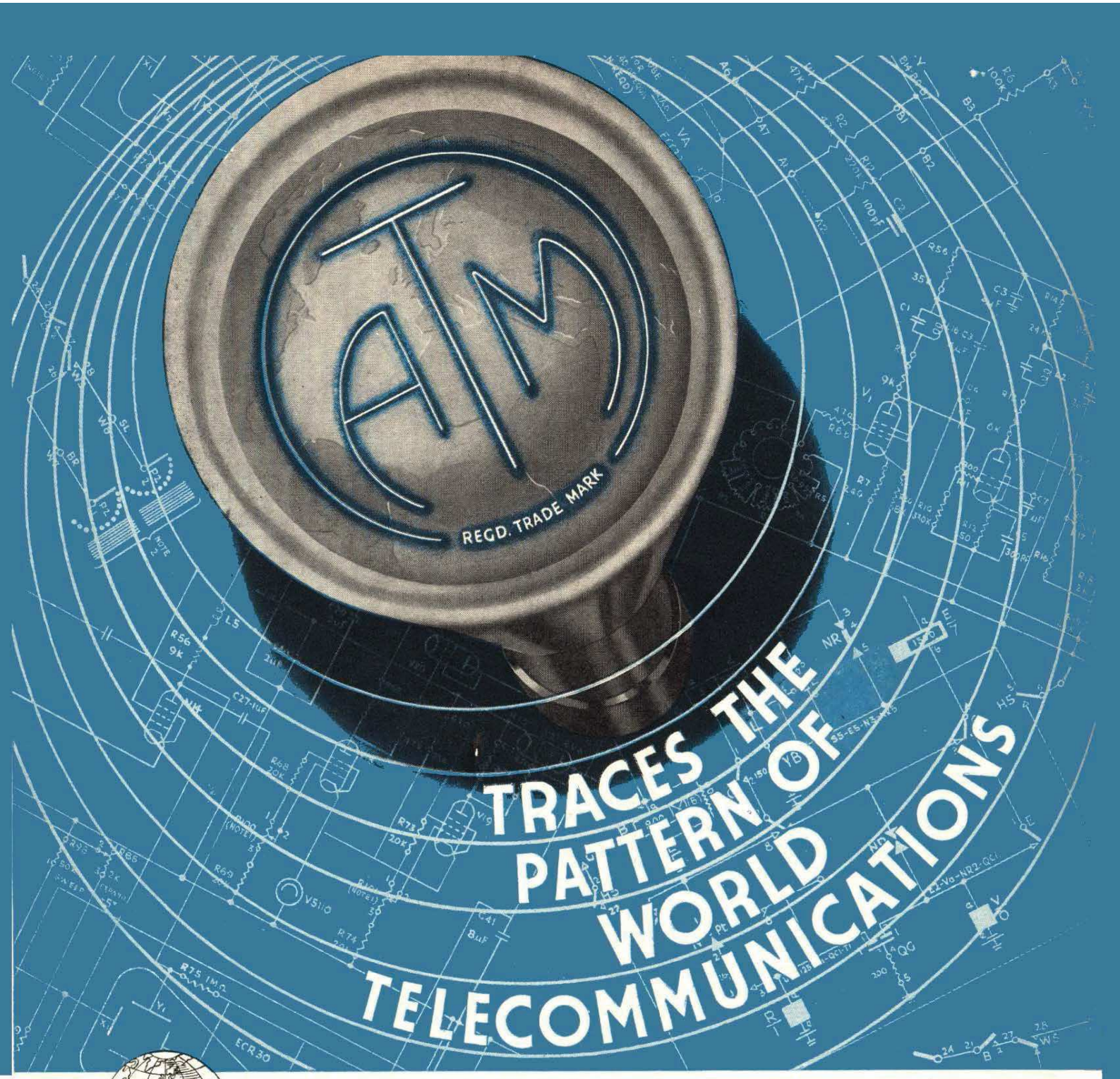
Telephone: New Cross 3255 (P.B.X.)

Electrical Standards for Research and Industry

Testing and Measuring Apparatus for Communication Engineering



A SERIES OF METAL CASED HIGH FREQUENCY UNITS ARRANGED IN DEGREES OF ATTENUATION IN ASSOCIATION WITH SPECIALLY DESIGNED SWITCHES HAVING FINELY LAMINATED BRUSHES



TRACES THE PATTERN OF WORLD TELECOMMUNICATIONS

THE pattern of world telecommunications is varied and complex. Varied because every problem requires an individual approach, involves a new assessment of available knowledge and a fresh consideration of existing methods of solution; complex because of all branches of engineering it is by far the most abstruse, involving in its approach to world communication problems the profoundest researches into physics and the development of special higher mathematical formulæ. This is the scientific background of the vast A.T.M. organisation which has at its disposal the specialised knowledge of over 50 years' experience in the telecommunication art and which has been responsible for many of the major inventions and discoveries in the subject during this period.

The scope of telecommunications is so vast that it requires the Company to employ the services of a large number of specialists in many subjects including acoustics, thermionics, electronics, piezo-electric and photo-electric phenomena, transmission theory, power engineering and measurement; it follows that such a body of collective knowledge is instantly available to deal with any problem for which the application of one or more of these techniques can provide a solution.

The scientific background of the Company is allied to an efficient organisation producing the following :—

TELEPHONE EXCHANGES FOR NETWORKS OF ANY SIZE

Director Exchanges for metropolitan and large provincial areas. Non-director main and satellite exchanges

Automatic and automanual trunk exchanges

Manual exchanges

Private automatic exchanges (P.A.X.)

Private automatic and manual branch exchanges (P.A.B.X. and P.M.B.X.)

Calling line identification equipment

Press Button telephone systems from 5 to 15 lines with or without loudspeaker master stations

TRANSMISSION EQUIPMENT

Single, three, twelve and twenty-four-channel carrier telephone systems for overhead lines or underground cables. Six, twelve, eighteen and twenty-four-channel carrier telegraph systems

Loading coils

Quartz crystals

Carrier and audio repeaters

Transmission testing apparatus

SIGNALLING EQUIPMENT

V.F. Systems of signalling and dialling using C.C.I.F. codes

500/20 c/s signalling equipment

Long-distance D.C. impulsing systems

50 c/s dialling equipment

REMOTE CONTROL SYSTEMS

Systems of remote control with indication and telemetering equipment for the following services:

Electricity distribution networks

Electric railways; tram and trolleybus transport undertakings

Gas distribution networks

Water distribution networks

Oil distribution networks

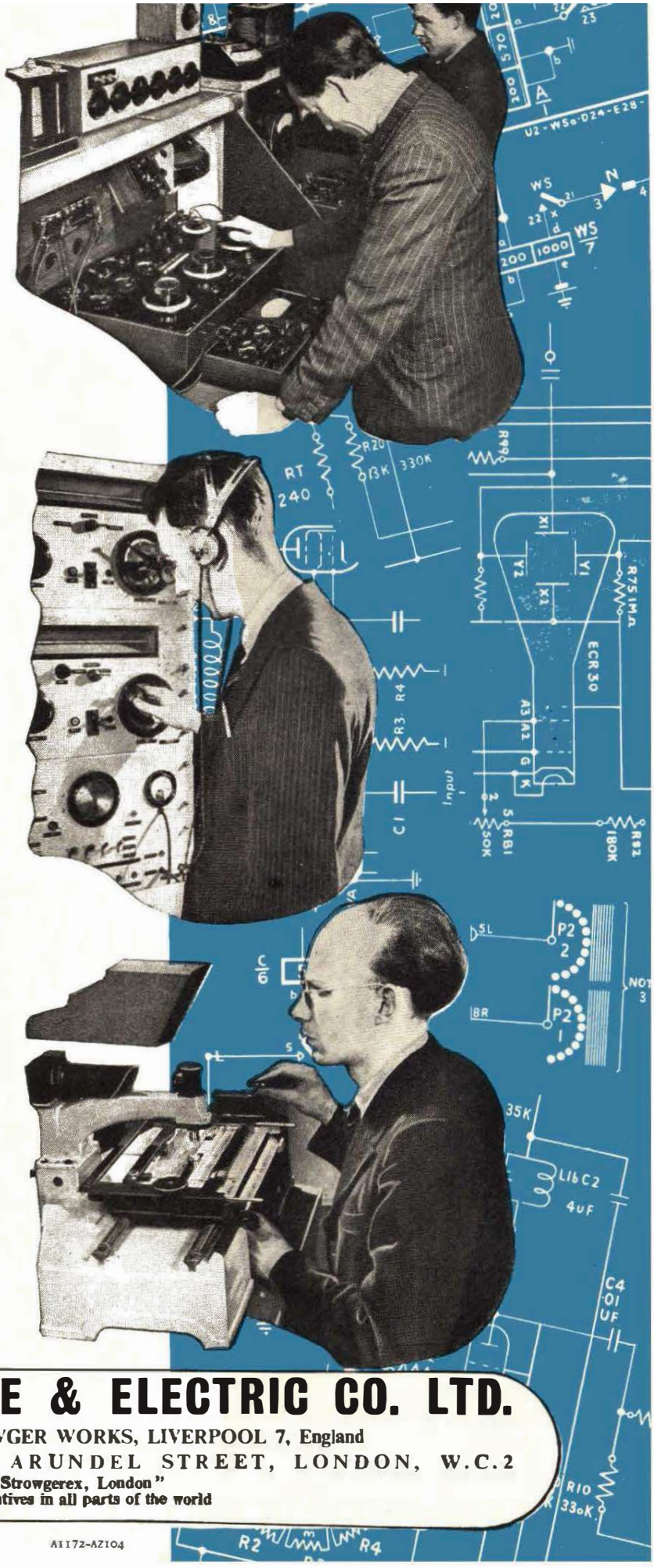
"Rythmatic" ripple control systems for street lighting, selective load control and other operations

LIGHT CURRENT SIGNALLING SYSTEMS

Mine telephones and signalling equipment

"Electro-matic" vehicle-actuated traffic signals for simple and complex intersections. Interlinked systems

ELECTRONIC DEVICES



AUTOMATIC TELEPHONE & ELECTRIC CO. LTD.

Registered Office and Works: STROWGER WORKS, LIVERPOOL 7, England

Export Department: STROWGER HOUSE, ARUNDEL STREET, LONDON, W.C.2

Cablegrams: "Strowgerex, London"

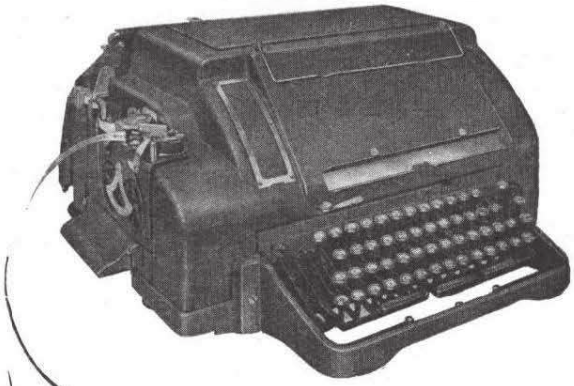
Agents and Representatives in all parts of the world

AI172-AZ104

Creed

TELEPRINTERS

Built by specialists in machine telegraphy~

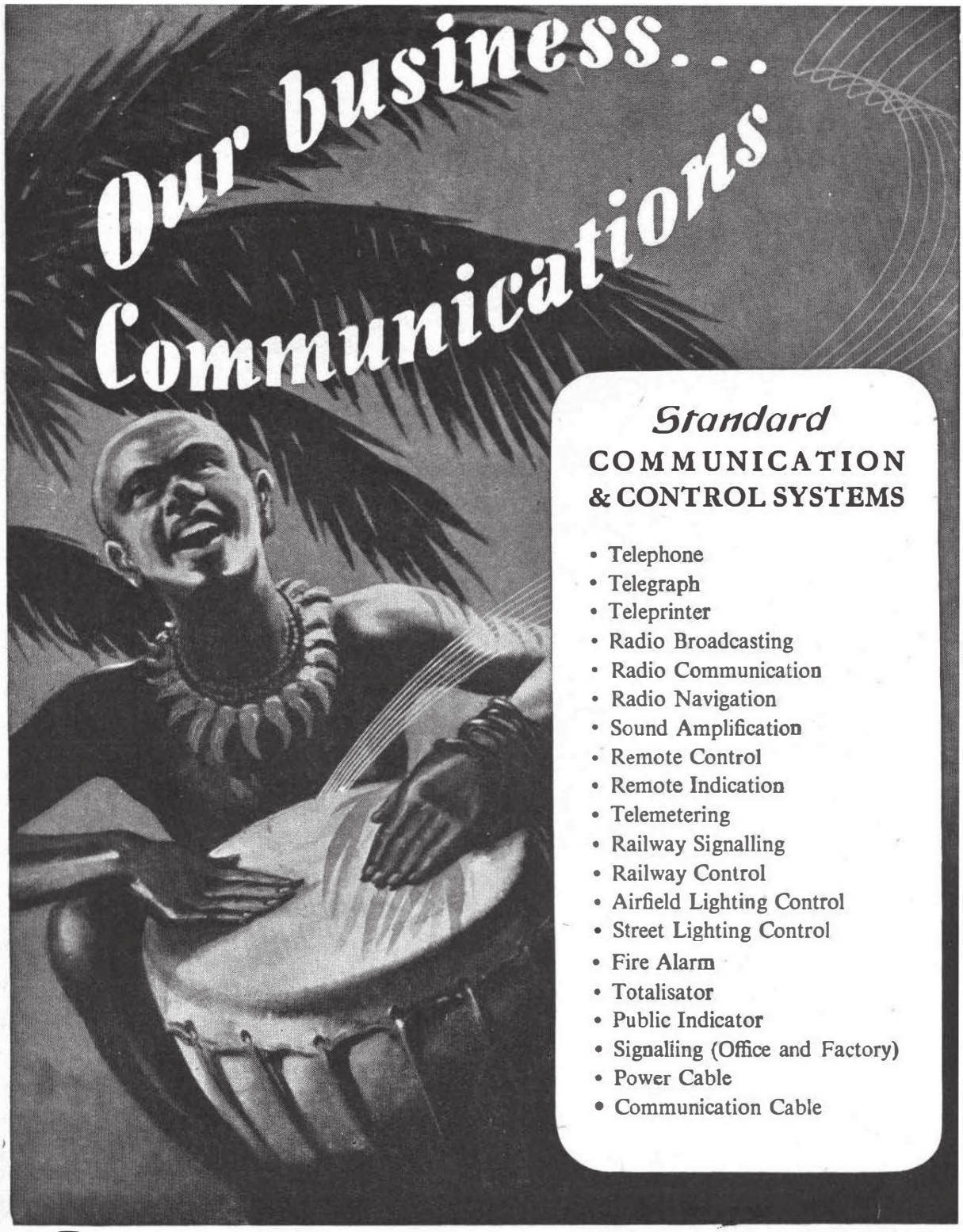


N° 47 TAPE MODEL

Write for Bulletin N° 21

Creed & Company Limited

TELEGRAPH HOUSE
CROYDON, ENGLAND



Standard
COMMUNICATION & CONTROL SYSTEMS

- Telephone
- Telegraph
- Teleprinter
- Radio Broadcasting
- Radio Communication
- Radio Navigation
- Sound Amplification
- Remote Control
- Remote Indication
- Telemetering
- Railway Signalling
- Railway Control
- Airfield Lighting Control
- Street Lighting Control
- Fire Alarm
- Totalisator
- Public Indicator
- Signaliing (Office and Factory)
- Power Cable
- Communication Cable

Standard Telephones and Cables Limited

TELECOMMUNICATION ENGINEERS

CONNAUGHT HOUSE, ALDWYCH, LONDON, W.C.2

Overseas Branch Offices: Cairo · Calcutta · Dublin · Johannesburg · Karachi · Salisbury

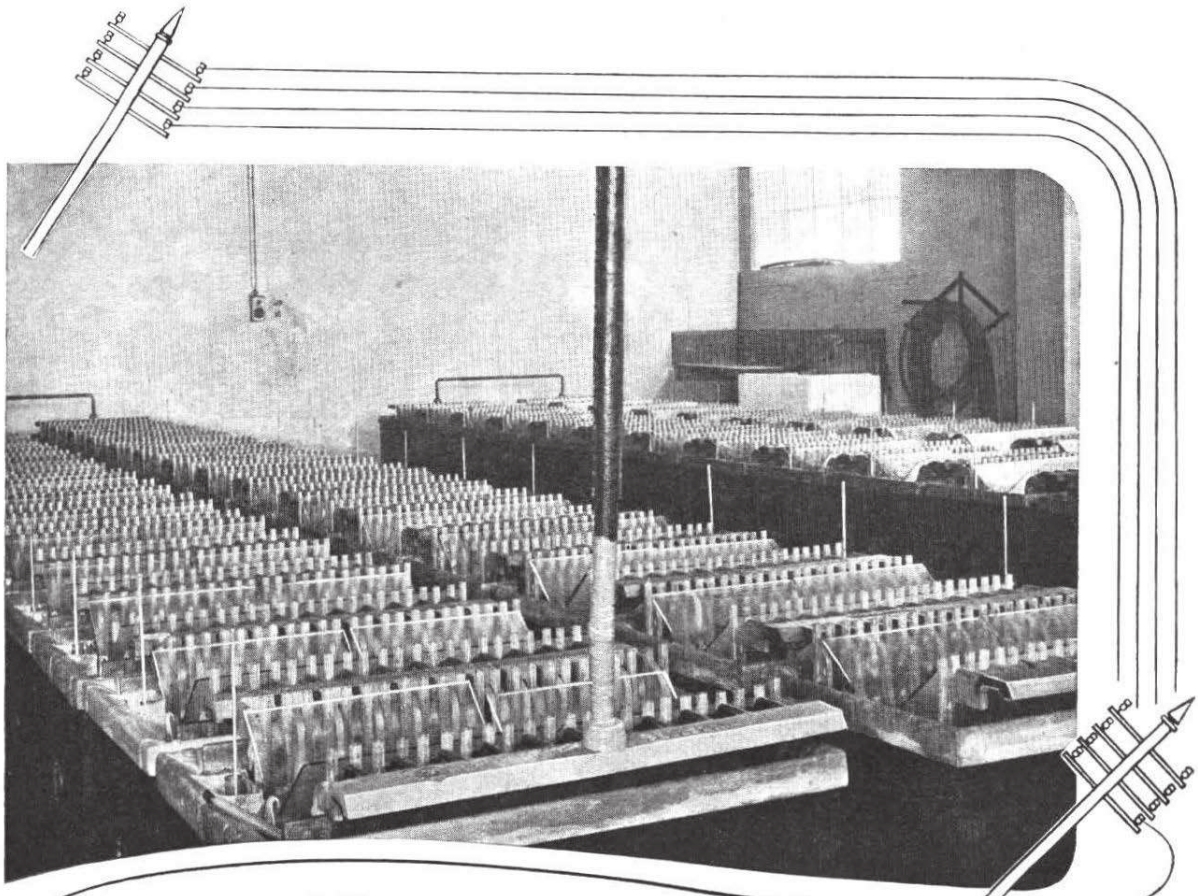
. . and we repeat . . .

ERICSSON AUTOMATIC DIALS
are British Post Office Standard. Uniform pulsing. Impulsing contacts, gold, silver, platinum. Normal finish, black with black figures on white ground. Normal impulse ratios — 33% make, 66% Break. Can be supplied with neat dust cover with stainless steel finger plate and with sockets suitable for mounting in either the horizontal or vertical plane. Instruction labels and number plates can be arranged to suit customers' requirements.

Ericsson

AUTOMATIC DIAL SWITCHES

ERICSSON TELEPHONES LTD. · *Head Office:* 22 LINCOLN'S INN FIELDS, LONDON, W.C.2 · *Tel:* HOL 6936
Works: BEESTON, NOTTS.



POWER BEHIND THE LINES

TUNGSTONE PLANTÉ CELLS are being supplied to the British Post Office and Post and Telegraph Departments in many countries overseas. They conform fully to G.P.O. and British Standard specifications.

OPEN TYPE CELLS

Similar to the illustration above, these are available in glass and/or lead lined wooden boxes in capacities from 100 a.h. to 500 a.h.

ENCLOSED TYPE CELLS

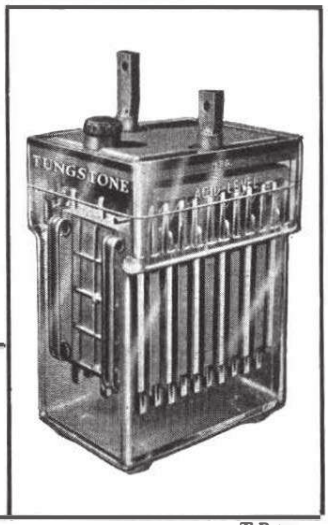
As illustrated on the right, these are in moulded glass boxes with sealed-in lids. Capacity range from 10 a.h. to 200 a.h.

REPLATALS

We are in a position to supply plates for the replating of any existing Planté Battery.

HIGH VOLTAGE TELEPHONE BATTERIES

Portable Type. Standard layout for 50 volts, in waxed hard wood crates, exactly to the requirements of the G.P.O.



Overseas customers are invited to cable or write their enquiries for batteries or parts. Visitors to London are welcome at our offices.

TUNGSTONE *Batteries*

For further particulars write : **TUNGSTONE PRODUCTS LIMITED**
10 SALISBURY SQUARE · LONDON · E.C.4 · ENGLAND. Cables: "Dilutum" London.

T.B.12

How to keep the Night Watchman Awake!

Eversheds are sometimes called upon to supply recorders for strange purposes. Once a firm even purchased an Evershed Recorder to keep the night watchman awake! This particular individual had important duties to perform in processes left unattended during silent hours, and the recorder chart gave the management a precise picture of exactly how well the job was being done. As in many other industries a permanent record was wanted of information normally available for a fleeting second.

Industrial concerns, public undertakings, development engineers and research scientists alike pay tribute to the reliability of Evershed recorders, which can be used without supervision in unattended stations. Abnormal demands, unexpected fluctuations and excessive loads can all be studied, and suitable precautionary measures taken to prevent overloading and reduce unnecessary expenditure. In fact Evershed recorders give a visual picture of exactly what took place, and when it occurred.

continued in next column

EVERSHED TEST THE WIRE!

Infinite care is taken with every detail in the manufacture of Evershed instruments.

Before wire is used, for example, it has to pass through a special 'wire-tester' designed in the Evershed laboratories.

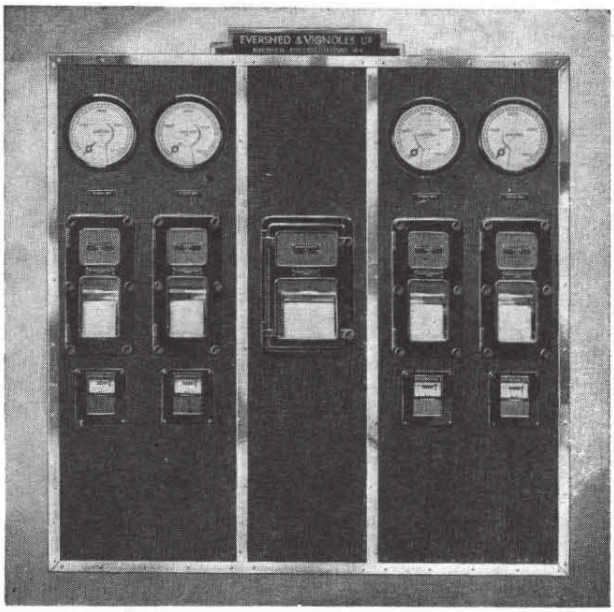
Only then is it handed on to the production department.

U.S. ADVISED 'USE MEGGER TESTERS'

The American Associated Factory Mutual Fire Insurance Companies advocate annual check of earth resistances and say "the 'Megger' Earth Tester is easiest, quickest and most accurate method of doing this".

EVERSHED

PROCESS CONTROLLERS
INDICATORS AND RECORDERS
REMOTE CONTROLLERS
MEGGER TESTERS



Evershed Recorder Panel for distant indication and recording of electrical loads in a modern film studio.

Here are a few of the many purposes for which Evershed recorders are now being used:—

A cigarette manufacturer uses them to check the weight of packets as they come off production lines.

New Zealand railways keep a permanent record of shunting operations and thus study the most efficient methods.

The Post Office Engineering Department records the volume of telephone traffic.

The British Electricity Authority has Evershed recorders in power stations to record the outputs of generators, consumer demands, purity of boiler feed water and all kinds of valuable data. Portable models are used to obtain information on network conditions.

Water and sewage undertakings keep accurate records of the number of pumps in operation at any time.

Manufacturing concerns purchasing electrical power have installed Evershed maximum demand recorders for restricting peak loads and avoiding special tariff charges.

Railways and tramways carry out traction tests with Evershed recorders.

And these are only a few applications. If you would like to know more about Evershed recorders, write today for

Publication . . . X 222

EVERSHED AND VIGNOLES LIMITED

ACTON LANE WORKS · CHISWICK · LONDON · W4

Telephone: Chiswick 3670. Telegrams: Megger, Chisk, London
Cables: Megger, London

5/135

FERRANTI

7-Range CLIP-ON AMMETER

RANGES

0 – 10 Amps.
0 – 25 "
0 – 50 "
0 – 100 "
0 – 250 "
0 – 500 "
0 – 1000 "

FERRANTI

Thumb-operated switch

Fully insulated

Accuracy within 3% of full scale

Can be applied to bare or insulated conductors up to 2¼ins. diameter

Weight...3lbs.

Delivery from Stock

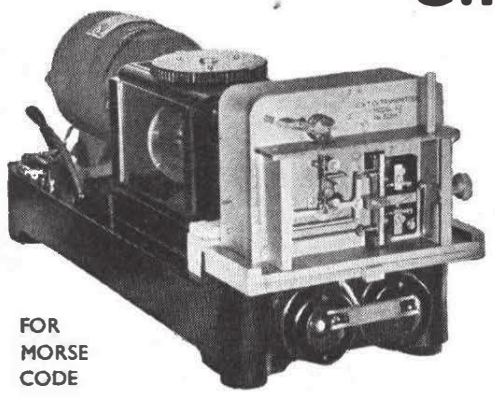
FI 69

FERRANTI LTD., HOLLINWOOD, LANCS.

London Office: Kern House, Kingsway, W.C.2

UNIVERSALLY ADOPTED

G.N.T.Co. TRANSMITTER MODEL 112



FOR MORSE CODE

13-250 words per minute without gear changes or readjustments.

Absolutely constant speed at all settings notwithstanding large voltage variations.

Noted for its easy maintenance.

Supplied with A.C. or D.C. motors as required.

THE GREAT NORTHERN TELEGRAPH CO. LTD.

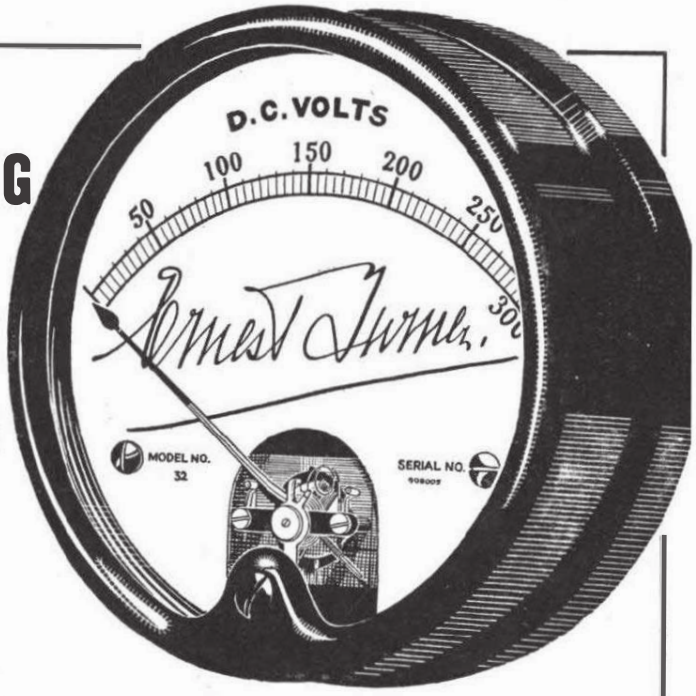
OF DENMARK

KONGENS NYTORV 28
COPENHAGEN K. - DENMARK

AND

5, ST. HELEN'S PLACE,
LONDON, E.C.3

ELECTRICAL MEASURING INSTRUMENTS OF THE HIGHER GRADES

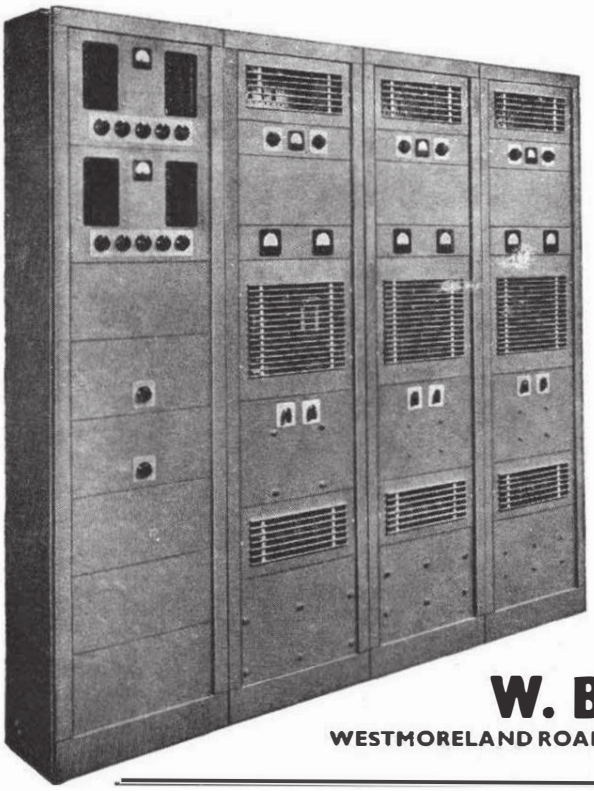


ERNEST TURNER ELECTRICAL INSTRUMENTS LTD.

CHILTERN WORKS, TOTTERIDGE AVENUE, HIGH WYCOMBE, BUCKS.

Telephone : High Wycombe 1301/2

Telegrams : Gorgeous, High Wycombe



The Mark II series of

SAVAGE AMPLIFIERS

for Broadcast Relay

These Amplifiers are examples of what careful design can achieve. A lift-off back panel affords immediate access for maintenance purposes and the removal of six screws releases the side covers of the rack and exposes all the interpanel wiring. Even when the rack is sandwiched between others the side covers can be moved just as easily. All valves are accessible from the front of the rack, and are protected by quick release grilles. The rack is completely flat fronted. The general appearance is further enhanced by the absence of a projecting front foot, and the masking of all panel fixing bolts. Similar racks carrying auxiliary apparatus can be placed side by side with amplifiers so that the whole installation is uniform in appearance.

Complete specifications available on request.

W. BRYAN SAVAGE LIMITED

WESTMORELAND ROAD · LONDON N.W.9 · TELEPHONE: COLINDALE 7131

Denso

Regd. Products

has your Corrosion Problems TAPED

Denso Tape protects mains, services and all metalwork, below or above ground, against the menace of chemical and electrolytical corrosion. Ideal for water- and gas-proofing and an aid to frost-proofing. Emergency repairs to gas mains and services. Water-proofing temporary cable openings.
Specifications and Price Lists of "Denso" Anti-corrosive and Sealing Products without obligation from :—

WINN & COALES LTD.

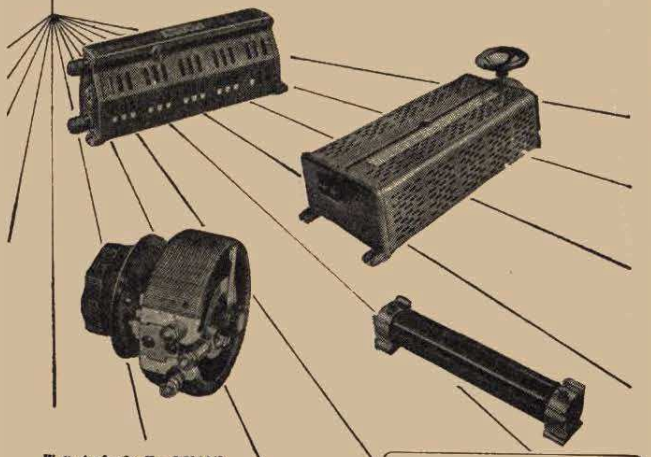
TERMINAL HOUSE, GROSVENOR GARDENS, LONDON, S.W.1
Telephone : SLOane 6146/7. Telegrams : DENSELTE, SOWEST, LONDON

Electronics in Industry

For twenty years our Engineers have been forerunners in the design and manufacture of resistances, anticipating and solving the many problems continually arising in the development of the use of electronics in industry.

That's why engineers today have every confidence in specifying BERCO resistances (fixed, sliding, rotary and wire wound); why they place their problems before us knowing that our years of experience in this branch of electrical products enable us to tackle any job satisfactorily.

May we offer our services to you !



Write for Leaflet No. BR102/2

THE BRITISH ELECTRIC RESISTANCE CO. LTD.
Queensway · Ponders End · Middlesex
Telephone : Howard 1492 Telegrams: Vitrohm Enfield

BERCO

B.R.1021-A.Q.1

SOUND INSTRUCTION by Postal Method

The I.C.S., largest school in the world devoted to spare-time training by the postal method, offers you highly specialised Courses for the following examinations :

P.M.G. Certificates for Wireless Operators.
C. & G. Illumination Engineering (Inter.)
C. & G. Electrical Engineering Practice, Installation and Telecommunications.
Graduateship of the B.I.R.E.

I.C.S. Examination students are coached till successful.

Other Courses meet the requirements of all who desire to qualify for responsible positions in Electric Power, Illumination, Heating and Traction Systems. Equally successful is our instruction for Telegraph and Radio Engineers, Radio Servicemen, and in Elementary Radar and Electronics, Advanced Short-Wave Radio and Television Technology.

Instruction is by correspondence from textbooks specially prepared by many experts.

WRITE FOR OUR SPECIAL BOOKLET and state the particular subject or Examination in which you are interested.

YOU MAY USE THIS COUPON

International Correspondence Schools Ltd.
Dept. 108, International Buildings, Kingsway, London, W.C.2

Please send me, free of charge, your special booklet on.....

Name..... *Age*.....
(BLOCK LETTERS, PLEASE)

Address.....

.....

ICS

PITMAN'S
for Technical Books

Power System Interconnection

By H. Rissik. The Second Edition of this important work. Thoroughly up-to-date, it is invaluable to the practising electrical engineer and is a reliable textbook for the advanced student. 25/- net.

Electric Cables

By Francis W. Main, M.I.E.E. A practical guide to the properties, construction, installation and maintenance of electric cables. The new edition contains up-to-date information on super-tension cables and other modern developments. With 52 illustrations. Third Edition. 12/6 net.

Electrical Technology

By H. Cotton, M.B.E., D.Sc., M.I.E.E. A standard textbook and reference work for electrical engineers and students, now completely revised and with important new material. Sixth Edition. Illustrated. 18/- net.

PITMAN, *Parker Street, Kingsway, London, W.C.2*

TELEPHONE CABLES

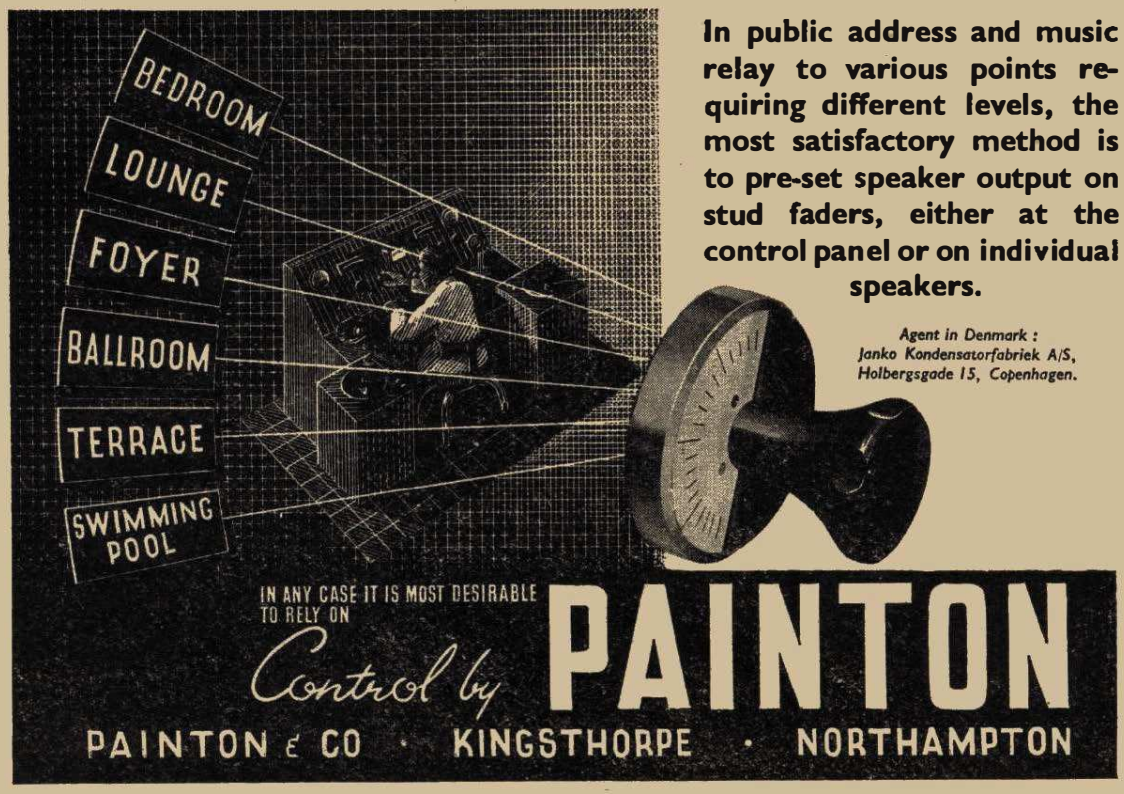
OUR BROCHURE No. 9E (1949), GIVING INFORMATION AND SPECIFICATIONS FOR A WIDE RANGE OF TELECOMMUNICATION CABLES MANUFACTURED BY US, IS AVAILABLE UPON REQUEST.

TELEPHONE: SOUTHAMPTON 2141 (5 lines).

PIRELLI-GENERAL

CABLE WORKS, Ltd., SOUTHAMPTON.

TELEGRAMS "PIGEKAYBEL SOUTHAMPTON



In public address and music relay to various points requiring different levels, the most satisfactory method is to pre-set speaker output on stud faders, either at the control panel or on individual speakers.

Agent in Denmark : Janko Kondensatorfabriek A/S, Holbergsgade 15, Copenhagen.

IN ANY CASE IT IS MOST DESIRABLE TO RELY ON

Control by PAINTON

PAINTON & CO · KINGSTHORPE · NORTHAMPTON

Printed by SANDERS PHILLIPS & CO., LTD., The Baynard Press, Chryssell Road, London, S.W.9, and Published by BIRCH & WHITTINGTON (*Prop. Dorling & Co. [Epsom], Ltd.*), Epsom, Surrey.

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

VOL. 43 JULY 1950 PART 2

CONTENTS

	PAGE
INTRODUCTION TO ELECTRONIC AUTOMATIC TELEPHONE EXCHANGES: SPEECH PATH SWITCHES AND LINE SIGNALLING—T. H. Flowers, M.B.E., B.Sc., M.I.E.E.	61
LOCAL LINE PLANT: PAIR APPROPRIATION RECORDS—A. Morris, A.R.C.Sc., D.I.C., Wh.Ex., M.I.E.E., and W. H. Dolan, B.Sc.(Eng.), A.M.I.E.E.	69
DESIGN OF SQUARE-LAW RECTIFIER CIRCUITS FOR MEASURING INSTRUMENTS—D. C. Walker, B.Sc.(Eng.), A.M.I.E.E., D. L. Richards, B.Sc.(Eng.), A.M.I.E.E., and G. P. Horton, B.Sc.(Eng.)	74
A SURVEY OF MODERN RADIO VALVES—Part 5—Valves for Use in the Range 30-3,000 Mc/s (Bands 8 and 9)—R. W. White, B.Sc., F.Inst.P., A.M.I.E.E.	78
A POLARISED RELAY OF IMPROVED PERFORMANCE—H. A. Turner, B.Sc.(Eng.), A.M.I.E.E., and B. Scott, M.B.E., M.B.A., B.Sc.(Eng.), A.C.G.I., A.M.I.E.E.	85
THE LONDON-CASTLETON EXPERIMENTAL RADIO-RELAY SYSTEM—A. H. Mumford, O.B.E., B.Sc.(Eng.), M.I.E.E., Capt. C. F. Booth, O.B.E., M.I.E.E., R. W. White, B.Sc., F.Inst.P., A.M.I.E.E.	93
OLIVER HEAVISIDE—An Appreciation—Sir George Lee, O.B.E., M.C., B.Sc., Past President I.E.E.	100
Notes on the Centenary Meeting, 18 May, 1950—W. G. Radley, C.B.E., Ph.D., M.I.E.E.	101
THE ELECTRICAL POWER SYSTEM FOR HANDLING CABLE IN H.M.T.S. MONARCH—A. J. Thomson	102
NOTES AND COMMENTS	106
INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS	107
REGIONAL NOTES	108
JUNIOR SECTION NOTES	112
STAFF CHANGES	114
BOOK REVIEWS	68, 84, 99

Price 1/6 net

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

STUDY AT HOME

You Can Have a College Training For a Few Shillings Monthly

IN YOUR SPARE TIME

CITY and GUILDS
(Telecommunication)
EXAMINATIONS

The most progressive and most successful Correspondence College in the world

To every student we send a written Guarantee of Tuition until the examination is actually passed

Our tuition is so graded that each stage is reached without difficulty.

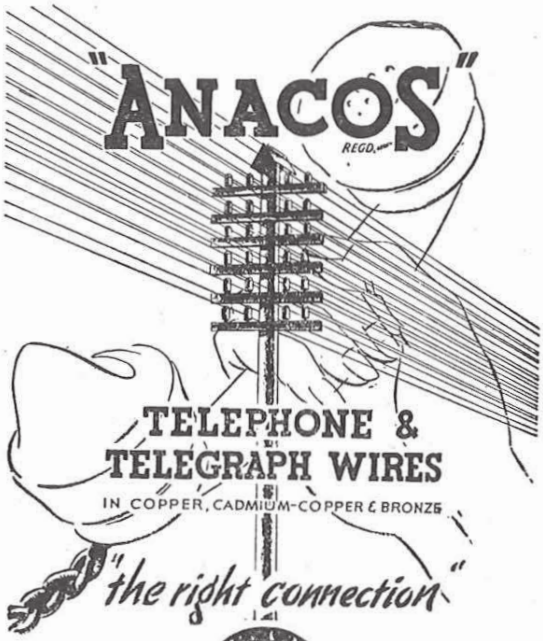
Personal attention is given to every student.

FULL PARTICULARS AND ADVICE SUPPLIED FREE.
WE TEACH BY POST IN ALL PARTS OF THE WORLD.

The Bennett College Limited

Dept. 24, THE BENNETT COLLEGE, SHEFFIELD

"ANACOS" REGD.

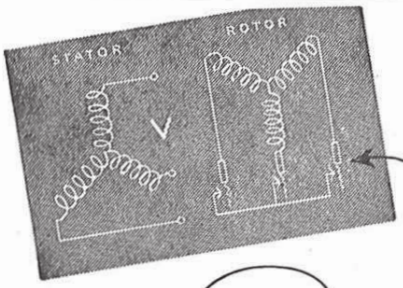


TELEPHONE & TELEGRAPH WIRES
IN COPPER, CADMIUM-COPPER & BRONZE

"the right connection"

FS

FREDERICK SMITH & COMPANY
(Incorporated in The London Electric Wire Company and Smiths, Limited)
ANACONDA WORKS, SALFORD 3, LANCS.
Phone: Blackfriars 8701 (9 lines) • Grams: "Anaconda," Manchester



A.C. Polyphase Wound Rotor - Rotor Rheostat.

FOR EVERY PHASE OF ELECTRICAL WORK

The British Electric Resistance Co. Ltd. can answer the multitude of resistance problems that beset the electrical circuit designer. For twenty years Berco resistances have been giving reliable and steadfast service, and the Berco range is designed to meet every requirement.

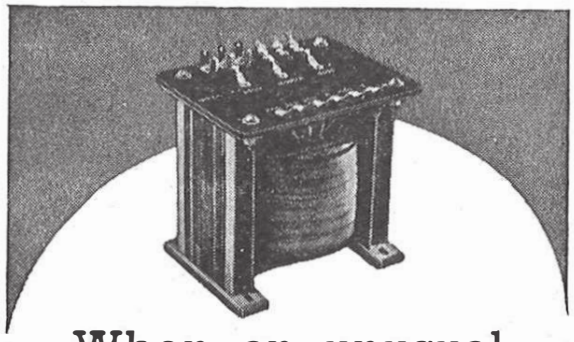
Berco engineers are specialists in resistance design and their knowledge is at your disposal.

BERCO

RESISTANCES

THE BRITISH ELECTRIC RESISTANCE CO. LTD.
Queensway, Ponders End, Middlesex
Telephone: Howard 1492 Telegrams: Vitrohm, Enfield

BR2033-AQ



When an unusual Specification is required.

We can give you the benefit of 20 years' experience in transformer construction and design. We manufacture quantities but we do NOT mass produce. Every Instrument is built to suit your most exacting individual specification.

Send your enquiries for the personal attention of our **Mr. W. Bryan Savage.**

TRANSFORMERS OF SAVAGE DEVIZES LIMITED

SAVAGE TRANSFORMERS LTD. • NURSTEED ROAD, DEVIZES, WILTS.

THE POST OFFICE
ELECTRICAL ENGINEERS' JOURNAL

Vol. 43 July, 1950 Part 2

Introduction to Electronic Automatic Telephone Exchanges: Speech Path Switches and Line Signalling

T. H. FLOWERS†, M.B.E., B.Sc., M.I.E.E.

U.D.C. 621.395.4 : 621.318.572

Recent advances in the application of electronic devices to switching have turned the attention of telephone engineers to the possibilities of electronic exchanges. Systems with electronic control of mechanical switches are already in existence, but the future of fully electronic exchanges is more obscure. This article introduces the problem of the fully electronic exchange by discussing the electronic switching of speech circuits. It shows how simple electronic elements may be built into switches by multipling, and how the same result can be achieved by multiplex telephony. It also indicates the primary means of controlling such switches by signals passed through them. Further aspects of the subject will be introduced in later articles, the next of which will deal with translating registers, one form of which is the familiar director.

Introduction.

ELECTRONIC is a term applied to a variety of devices the action of which has to be explained in terms of the behaviour of electrons. These devices include as their most important members hot-cathode vacuum and gas-filled valves, cold-cathode gas-filled valves, rectifiers and cathode-ray tubes. Electronic apparatus and the techniques of using them have become basic to telephone speech transmission over all but the shortest distances. In the switching field, although the basic techniques of using electronic devices have been known for many years, practical application is not so advanced as in the transmission field. Nevertheless, even before the recent war, there was a movement in the direction of replacing heavily worked mechanical switches by electronic switches in order to increase the reliability of the switching, and during the war this process was accelerated, notably in the direction of fully electronic computors which reached giant proportions. This work greatly advanced the knowledge and practical experience of electronic switching devices, one of the results of which was an increased confidence in the ability of electronic switching apparatus to compete with electro-mechanical apparatus in cost and reliability.

Since the war, attention has been given by telephone engineers to the possibilities of partially or fully electronic automatic telephone exchanges, and it is not inconceivable that the systems of the future will be fully electronic. There are already in operation systems in which electronic devices are incorporated to control electromagnetic switches which carry the speech; the use of electronic devices as controlling elements in automatic exchanges is fairly well known and understood. The switching of speech circuits by the same means is known and practised in relatively simple applications, such as echo-suppressors, but the knowledge needed to switch and control speech circuits on the scale essential to a fully electronic exchange is only just beginning to emerge. This article discusses possible means of solving these problems.

†Assistant Staff Engineer, Research Station.

Telephone Exchange Switch

A telephone system is built up of exchanges which are interconnected by groups of transmission lines, and to which the subscribers' lines are connected. Manual board and other non-subscriber lines will be treated as subscribers' lines for the present purpose. A number of connections can simultaneously exist in the system, each connection comprising a bothway communication path from a subscriber's station over a line to an exchange, then either over another line on the same exchange to another station or over any number of junctions in series to another exchange, thence over a line connecting that exchange to another station. The establishment of a connection is a complex problem of switching and transmission.

For the present, we will consider only that part of the problem which is concerned with bothway speech transmission from one station in the system to any other. This can be reduced to the problem of a single exchange, as shown in Fig. 1. The rectangle

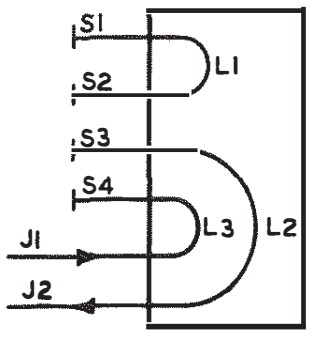


FIG. 1.—THE TYPES OF CONNECTION WHICH CAN BE MADE IN A SINGLE EXCHANGE.

represents an exchange to which stations S1, S2 . . . are connected by lines and to which groups of junctions to other exchanges, represented by J1 and J2, are similarly connected. The problem of connection of any station to any other is solved if (1) any station exchange line can be connected to any other station exchange line terminated on the same exchange as the first, (2) any station exchange line can be connected to at least some of the junctions in every group of junction lines, and (3) sufficient junctions and means of connecting lines together are provided to enable as many connections to be made simultaneously as may be desirable. In Fig. **1** the loops L1, L2 and L3 represent the connections which may be made within the exchange. In a manually switched system the loops are plugs and cords ; in an automatic system the loops are provided by switches.

Obviously one large switch, capable of accommodating all the subscribers' lines and the junctions and making all the necessary connections between them, would suffice, but is not practicable. It is well known to use smaller switches multipled in ranks, with the ranks in series, to produce the effect of one large switch. The size of the smaller switches determines the numbers required in each rank and the number of ranks. This question is important to the economics of any system. Its influence is indicated in the following discussion, which refers only to the talking paths through switches.

Element Switches.

An " element switch " may be defined as a switch not capable of division into smaller parts and having the following properties :—

(1) Two distinct sides.
(2) On one side, N sets of terminals to which speech circuits may be connected, one to each set of terminals.
(3) On the other side, M sets of terminals to which speech circuits may be connected, one to each set of terminals.
(4) When suitably controlled, the switch will connect any set of terminals on the N side to any set of terminals on the M side, and many such connections may be made simultaneously up to the limit of N or M whichever is the less.

To be sure that the idea of an element switch is clear, consider a number of examples from existing practice. A single 100-point Strowger switch with its bank has a wiper side and a bank side. The wipers provide one set of terminals, i.e. N = 1, which can be connected to any of the 100 sets of bank terminals, i.e. M = 100, and the limit to the number of such connections which may be made simultaneously is set by N = 1. Similarly for a 25-point uniselector, N = 1 and M = 25. For a relay, having make contacts, one set of terminals is provided by the make springs and one by the lever springs ; N = 1, M = 1, and only one connection can be made.

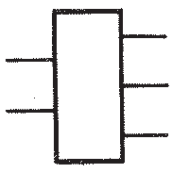


FIG. 2.—SYMBOL FOR AN ELEMENT SWITCH.

Fig. **2** is the symbol which will be used for an element switch having N sets of contacts on one side and M the other, and which will be called an N.M element switch.

Element switches may be formed into switches of larger capacity by the well-known process of multipling. In Fig. **3**, two element switches having N = 2

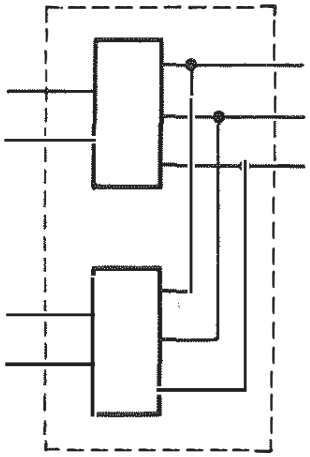


FIG. 3.—TWO ELEMENT SWITCHES MULTIPLED TO MAKE ONE 4.3 SWITCH.

and M = 3 are shown with the M-side terminals multipled together. The resultant switch, which is indicated by the dashed-line rectangle, is a 4.3 switch made up of two element switches. With x element switches all multipled together on the M side, the resultant would be a xN.M switch. If y of the xN.M switches are multipled on the xN side, making a total of xy element switches, then the resultant would be an xN.yM switch. Clearly, switches may be made as large as we please from any device which is capable of being adapted to make and break an electrical speech circuit.

Again illustrating the point from current practice, ten 100-point Strowger (1.100 element) switches are commonly multipled on their bank sides to form a 10.100 switch, and then into a larger switch by further multipling on the bank side. One 200-point Strowger switch is formed by taking two 1.100 switches (two 100-point banks and two sets of wipers) and multipling the wipers. The fact that in practice the wipers are switched and not obviously multipled is due to the mechanical construction of the switch, which compels both sets of wipers to move together. If the wipers could be moved independently, multipling of the wipers would suffice. A cross-bar switch is built up of relay 1.1 element switches, the relays being multipled first into 1.10 switches and then into 10 10 or 20.10 switches.

These two examples illustrate an important point. To provide a 100.100 switch from Strowger element switches requires 100 element switches. To provide a 100.100 switch from relays requires 10,000 relays, which is much more expensive. Hence 1.1 element switches are at a grave disadvantage unless they are extremely cheap. Small element switches are commonly multipled into smaller units than the bigger element switches, with the result that a greater number of ranks of switches is necesary for a given size of exchange. 10,000-line Strowger exchanges can be

provided by line finders and three ranks of switches; the same size of cross-bar exchange may have ten stages of switching. Even with the advantage that more than one connection can be set up through one switch, it is difficult for cross-bar systems to compete economically with systems based on larger element switches.

Electronic Exchange Switches Using Multipled Element Switches

A convenient starting point in the quest for an electronic exchange switch is the examination of all electronic devices which can be made to make and break an electrical speech circuit; an exchange may be built using any such device, although other questions, particularly economics, will enter into the final choice. Chief among the stated devices are valves, gas-discharge tubes, cathode-ray tubes and rectifiers. Examples of the use of these devices are the following.

Fig. **4** shows an element switch using a vacuum

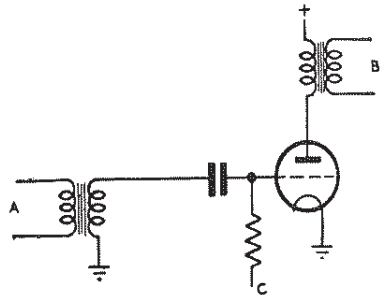


Fig. 4.—Element Switch Using a Vacuum Valve.

valve. A and B are the input and output terminals respectively, and C is a control lead. When the potential of C is a suitable negative value, A is electrically connected to B, and when its potential is more negative, A is electrically disconnected from B.

Fig. **5** shows a 2.2 switch built up of four element switches, in which inputs A1, A2 can be connected to B1, B2 by controlling voltages on the leads C11, C12, C21, C22. These switches have to be duplicated to provide transmission in both directions; transmission can be made very satisfactory by negative feed-back. The disadvantage of the switch is that it is composed of 1.1 elements which are not cheap.

Fig. **6** shows an element switch in which A is normally disconnected from B, but can be connected by causing a discharge to take place through the gas discharge tube GT. The discharge can be started and stopped by a suitable control voltage applied to C, the discharge once started being maintained by the battery E, and the current controlled by the resistor R. The capacitor, K, provides a low impedance loop circuit for the speech currents. Means of multipling the element switches can readily be seen. There are no hot cathodes to absorb power continuously, and the elements are relatively cheap. Transmission, which can take place in either direction, has to take account of the noisy and non-linear nature of the conduction through the gas.

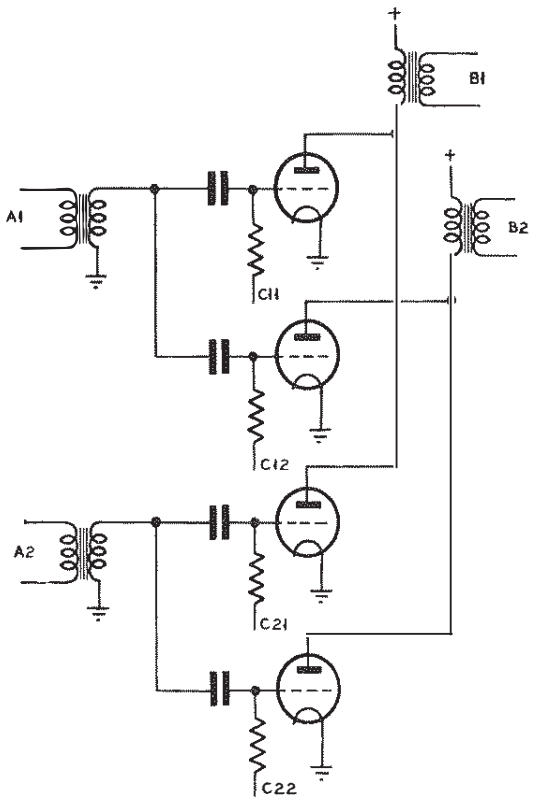


Fig. 5.—A 2.2 Switch, using Vacuum Valves, built up from 4 Element Switches.

Fig. **7** shows a circuit similar to Fig. **6**, but with a rectifier, QA, instead of the gas discharge tube. A is disconnected from, or connected to, B in dependence on the potential of C being above or below earth potential. Again transmission can take place in either

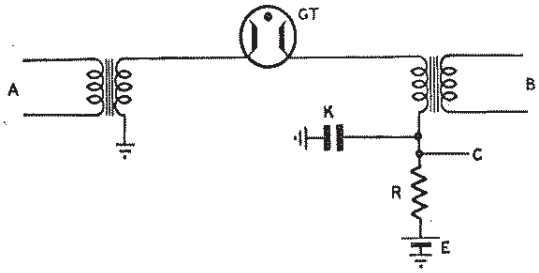


Fig. 6.—Element Switch using a Gas Discharge Tube.

direction; the rectifier is not noisy, but it is non-linear in its conduction and care is needed to prevent distortion of the speech currents.

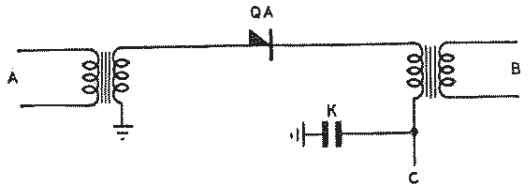


Fig. 7.—Element Switch using a Rectifier.

Fig. 8 shows a cathode-ray tube having an input circuit, A, to modulate the beam current, a number of contacts at the screen end of the tube, each contact being brought out to an output, B, and a set of

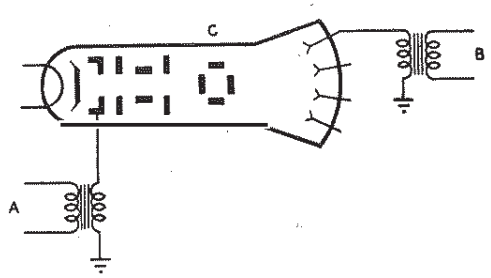


FIG. 8.—ELEMENT SWITCH USING A CATHODE-RAY TUBE.

deflector plates, C, the potential on which can be controlled to direct the beam to any desired output. The number of outputs can be as many as a hundred, and there are forms of construction, some involving secondary emission, by which bothway transmission can be provided by a single tube.

Cathode-ray tubes are expensive, but the fact that 1.100 element switches can be made is a compensatory advantage to a large extent. Their chief drawbacks are that the beam current is limited, so that the power which can be transmitted is small and considerable amplification individual to each channel B is necessary ; and the cathode life is at present too short to be economical for a telephone exchange.

The element switches so far discussed may find application in small exchanges, but for larger exchanges the multiplex switches, described in the next section, may be more economical.

ELECTRONIC SWITCHES USING MULTIPLEX ELEMENT SWITCHES

Multiplex transmission can be regarded as a form of multipling. Consider the element switch in Fig. 9.

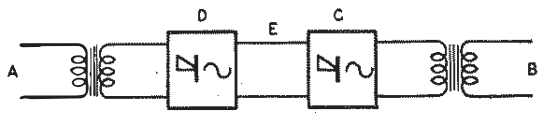


FIG. 9.—MULTIPLEX ELEMENT SWITCH.

An input, A, is connected through a modulator, D, to a common channel, E. A second modulator, C, may be controlled either to modulate or not to modulate the transmission from A back to audio frequency, whence A is either electrically connected or not connected to B. The modulation can be either by a carrier frequency (frequency-division multiplex), as in the familiar 12-channel and coaxial systems, or pulse modulation (time-division multiplex) as used, for example, in many radio links. The control applied to C may be the selection and switching on and off of the carrier frequency which will modulate back to audio frequency the transmission from D if it is there the modulation of a carrier frequency ; or the selection and switching on and off of a pulse which will select the pulse applied by modulator D if the input from A is pulse modulated by D. In both cases other apparatus not shown in the diagram is needed, for example, a filter, after the modulator C, to select the wanted audio frequency from the modulation products, and an amplifier after the filter to restore the level of the output at B to that of the input at A. If, now, a number of terminals B are provided, each with a modulator C (which can be controlled as previously described for C) and all terminals are connected to the common channel, E, then channel A can be connected to any channel B. If, further, a number of channels A with their modulators, D, are connected to the common channel, E, (the modulators, D, using different carrier frequencies or timed pulses to modulate the inputs at A) and if the modulators C can be controlled individually to select the transmission from any of the modulators D, then any A channel can be connected to any B. Two sets of equipment must be provided, one for transmission in each direction.

The terminals of a multiplex switch are expensive by comparison with other forms of element switch. The advantage of the method lies in this, that to produce an xN.yM switch, needs $x + y$ terminals instead of $x \times y$ element switches multipled in the usual way, and for large switches this is economically a very great advantage.

It will be appreciated that multiplex transmission introduced solely for the purpose of switching is different in several respects from similar transmission over long distances. In particular, the negligible length of the common transmission path means that greater band-width is available with less phase distortion and noise. Hence the terminals can be simplified ; frequency-division multiplexes can use wider channel spacings with, if desired, transmitted carrier and both sidebands, and time division can use amplitude modulation which is generally unsuitable for long-distance transmission. Frequency-division multiplex is familiar enough not to need detailed description. Time division is not so familiar and is described in the next section.

Pulse Modulation and Multiplex System.

An impulse is a single brief change of current and a pulse is a rhythmic train of impulses, as shown in Fig. 10 (*a*). Fig. 10 (*b*) shows a modulating voltage. In

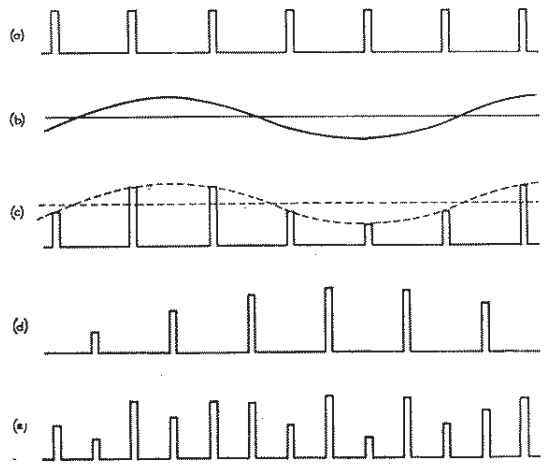


FIG. 10.—GRAPHS ILLUSTRATING THE PRINCIPLE OF TIME-DIVISION-MULTIPLEX TRANSMISSION.

(*c*) the wave of (*b*) is shown dotted and with its X-axis on the mean height, also shown dotted, of the impulses of (*a*). The full line shows the impulses which result when the impulses of (*a*) are modulated in amplitude by the wave (*b*). Provided that the frequency of the modulating source does not exceed in theory one-half, and in practice rather less than one-half, the impulse repetition frequency of the pulse, then the pulse can be demodulated back to the original wave (except that it is attenuated) by a low-pass filter. A second similarly modulated pulse, such as (*d*), the impulses of which are time-spaced so that they fall between the impulses of the first pulse, may be transmitted along with the first pulse over a common medium and without mutual interference, (*e*) showing the two pulses of (*c*) and (*d*) as a common transmission. For an electronic exchange switch, 100 equally time-spaced pulses may be desirable. The impulses, instead of being modulated in amplitude, may be modulated in a variety of other ways, for example, width or position relative to a mean width or position, but amplitude modulation is likely to be preferred for an electronic exchange switch because of its simplicity.

Fig. **11** shows in elementary detail an element switch

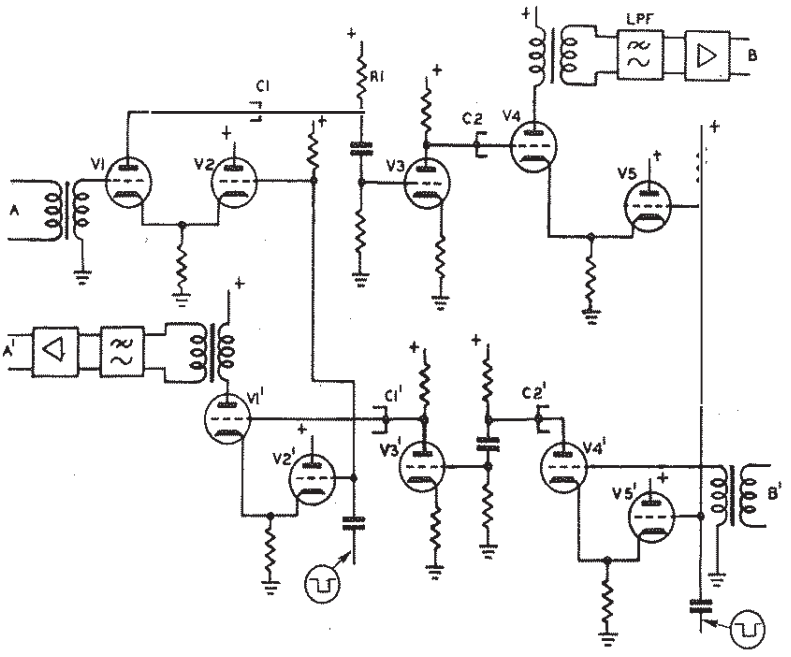


FIG. 11.—SIMPLIFIED CIRCUIT OF AN ELEMENT SWITCH USING PULSE MODULATION TO PROVIDE TWO-WAY COMMUNICATION.

using pulse modulation to provide two-way communication by 4-wire circuit between the channels A, A' and the channels B, B'. Channel A, which receives speech current from a trunk, is connected through a transformer to the grid of the valve V1 which, together with valve V2, forms a pulse amplitude modulator. The anode of V1 is connected to the anode positive voltage supply via resistor R1, and the cathode via a resistor to earth. Valve V2 has its cathode connected to the cathode of V1, and its grid via a resistor to a positive voltage such that normally the valve V2 conducts and raises the cathode potential so far above earth potential that V1 is cut-off. A negative impulse applied to the grid of V2 cuts off all anode current from that valve and causes V1 to conduct and thus to produce an impulse across the resistor R1. It is not difficult to see that if a pulse is applied to the grid of V2, with no input to A, there will be across resistor R1 a pulse similar to Fig. **10** (*a*), except that it is negative-going instead of positive, and that this pulse will be amplitude modulated by any input to A. The pulse across R1 has its polarity inverted by valve V3 and applied to a modulator including valves V4 and V5, and operating similarly to the valves V1 and V2. It is to be noted, however, that the input to the grid of V4 is a pulse and that only if the impulses of the pulse applied to the grid of valve V5 coincide with the impulses of the pulse applied to the grid of V4, is the pulse from V1 communicated to the anode of V4, where it is demodulated by the low-pass filter, LPF, and then amplified to deliver to B a replica of the input to A. Assuming the pulse connected to the grid of valve V2 is continuously maintained, channel A is connected to B only if there is connected to the grid of V5 a pulse coincident with that at V2; to use the apparatus as an automatic telephone switch means that the pulse applied to V5 must be controlled by the switch.

A transmission path from B' to A' similar to that from A to B can be traced, the pulses connected to the grids of the valves V2' and V5' being the same as those connected to V2 and V5 respectively. In this way a two-way-transmission element switch is produced. If now, further channels similar to A, A' have their modulators commoned to the commons C1 and C1', and the pulses to their valves V2 suitably time-spaced, and if further channels similar to B, B' have their modulators commoned to the commons C2 and C2', and the pulses to their valves V5 suitably controlled, any circuit having channels A, A' can be connected to any circuit B, B'.

Fig. **11** and the accompanying description is only one way in which a time-division multiplex switch may be constructed. There are many others. For example, rotating beam tubes, in which a pencil or ribbon beam of electrons sweeps cyclically over a series of electrodes, are known to produce the same result. It will also be understood, without detailed description, that an arrangement equivalent to Fig. **11** existsfor frequency-division multiplex. For example, the channels A, A' may be connected to modulators working with fixed carrier frequencies and the channels B, B' to modulators operated with carrier frequencies selected and connected according to the connections to be made through the switch.

General Properties of Electronic Exchange Speech Path Switches

The very brief outline review given of the possible forms which electronic exchange speech path switches may take is by no means exhaustive, but is sufficient to indicate the general properties which may be expected of such switches. It is also useful to compare electronic with electro-mechanical switches with metallic contacts. An electronic switch is unlikely to provide the facilities of a metallic contact switch that any amount of power from D.C. to a frequency of many kilocycles per second may be transmitted without attenuation, or gain, or distortion. It is probable that an electronic switch cannot be economically constructed to carry much more A.C. power than is needed for the speech itself. Most forms of switch will not transmit D.C. at all. Multiplex switches are specially limited in respect of frequency bandwidth and are unlikely to transmit a bandwidth much in excess of that needed for speech transmission. They have an advantage, however, in that by controlling the modulating carrier frequency or pulse, transmission through the switch of a signal equivalent to a D.C. signal can be achieved, but the power so transmitted is severely limited. It is, therefore, to be expected that, although speech transmission through an electronic exchange will nominally suffer neither attenuation nor gain, this result will be the sum of a series of losses due to attenuating elements and gains due to amplifiers, with all the attendant variations and non-linearities of such devices. It is also to be expected that, because in an electro-mechanical exchange system the capacities of the system in excess of the power and bandwidth capacity needed for speech transmission are used for controlling functions such as line signalling, ringing the subscriber's bell, and operating his meter, the controlling signals in an electronic exchange will be very different from those in the corresponding electro-mechanical exchanges.

Many of the possible forms of electronic switch provide only unidirectional channels so that 4-wire circuits through the switches are unavoidable. In effect, 4-wire switching even in local exchanges is, therefore, very likely ; in some systems it may prove essential in order to counteract the effect of the variation in loss or gain through the switches.

Signalling Through Electronic Switches

All electronic exchange switches must, of necessity, provide, through the switches, channels or circuits capable of transmitting A.C. at speech frequencies and powers ; at some cost in money the transmitted frequency band can always be extended in one or both directions, that is, to sub-audio and/or super-audio frequencies, and the transmitted power handling capacity increased to perhaps two or three times that needed to carry speech currents. Although some electronic exchange switches provide D.C. signalling channels as well as A.C. channels through the switches, the D.C. channels will not in general carry all the required signals. The most general problem which is presented is that of signalling with A.C. with a minimum of frequency bandwidth and power handling capacity over that needed for speech transmission.

It will be understood that in a fully electronic exchange system the signals will for the most part be required to operate, for example, valves where voltage into a high impedance, i.e. small power, is sufficient. The limited power handling capacity of the switches is, therefore, no handicap except for ringing over a subscriber's line or operating his meter. This problem is considered separately later. For all other purposes, A.C. signals at low power can suffice ; the problem is to find the channels for the signals and economical means of controlling and detecting them. Clearly one solution to the channel space problem is to provide separate speech and signalling channels through the switches, the exact analogy in electro-mechanical systems of speech and private wires through the switches. Secondly, if the channel which carries the speech currents transmits a band of frequencies wider than the speech currents need, signals can be transmitted over the channel and separated from the speech by filters.

Several means are known of electronically controlling alternating currents in the manner required for signalling. One is shown in Fig. **12**. An A.C.

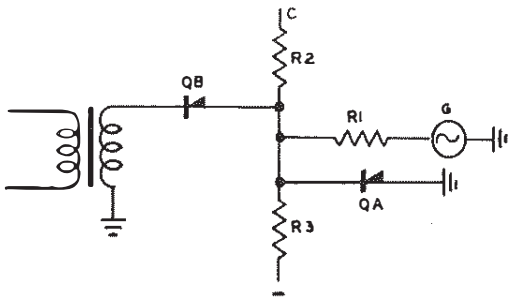


Fig. 12.—A Method of Controlling A.C. for Signalling Purposes.

generator, G, usually common to a number of switches and having one side earthed, is connected through a resistor, R1, to a network of resistors, R2, R3, and rectifiers, QA, QB, the lead, C, being the control lead and resistor, R3, being connected to a negative potential. Rectifier QB is connected to a transformer, the primary of which is earthed on one side and the secondary connected to the signal circuit. If lead C supplies no current to the circuit, rectifier QA has current through it in its low resistance direction ; the rectifier, QB, is biased to its high resistance condition. The attenuation between the generator and the signal channel is thus high, commonly 60 db. or more. If now the potential of lead C becomes sufficiently positive with respect to earth, rectifier QA becomes biased to its high resistance condition, and QB to low resistance. The attenuation between the generator and the signal channel is thus low, a few decibels perhaps. This element requires a D.C. controlling signal to control an A.C. transmitted signal. If the controlling signal is itself derived from an A.C. received signal from some other part of the system, rectification, possibly after amplification, of the received A.C. signal, will produce the required D.C. controlling signal.

Detection of signals is a matter of recognising the signals and producing from them the currents or

voltages required. Recognition of an A.C. signal may need tuned circuits or filters if more than one signal can be received over a channel. The received A.C. signal may be usable as such, or it may need to be transformed into D.C. by rectification; if it is required to be transformed into a signal at a different frequency, transformation into D.C. to control an A.C. source at the new frequency is the usual procedure. Amplification may be necessary to obtain sufficient power in the signal. Amplification of A.C. signals is simple with hot-cathode valves. Amplification of D.C. signals may be performed directly by hot-cathode valves used as cathode followers, or sometimes by cold-cathode tubes, and indirectly by converting the D.C. to A.C., amplifying and reconverting to D.C.

The purpose of the illustrations which have been given is not to discuss all the possible ways of signalling through electronic switches but to indicate that, because A.C. can be readily converted to D.C., D.C. to A.C., and either amplified, it is almost a matter of indifference whether the switches will transmit A.C. or D.C. at low or high power. It would be a matter of indifference if cost and complication did not enter into the question, and the practical problem is to keep these factors within acceptable limits. As an example of the sort of problem presented, and a possible solution, a circuit arrangement for subscriber's equipment is shown in Fig. **13**, this circuit being based on the assumption of 4-wire switches capable of transmitting only low power A.C. but with a frequency bandwidth greater than that needed for speech transmission.

In Fig. **13**, A and B are the two wires of a subscriber's line. A speech path exists from these two wires, through the hybrid transformer T1 and capacitor C1, and low-pass filter FT1 to the transmit channel of the 4-wire circuit through the switches. A

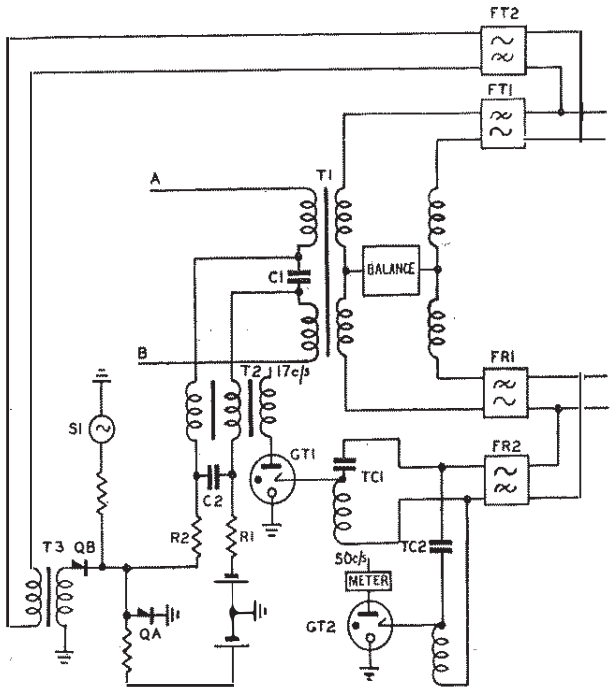


FIG. 13.—A CIRCUIT ARRANGEMENT FOR A SUBSCRIBER'S EQUIPMENT.

speech path also exists from the receive channel of the 4-wire circuit, through the low-pass filter FR1 and the hybrid T1 to the subscriber's line. A.C. signal paths independent of the speech path are provided through the high-pass filters FT2 and FR2 for the transmit and receive directions. Feeding current for the station transmitter, and controlling signals depending on the cradle switch, are derived from the battery which supplies current through the resistors R1 and R2, the secondary windings of a transformer, T2, and the 2-wire windings of the hybrid T1. The battery is tapped so that it produces both positive and negative potentials relative to earth. The positive terminal produces current which, when the A and B wires are not looped, flows through rectifier QA, rectifier QB thus being high resistance, and inserts a high attenuation path between the super-audio A.C. signal source S1 and the filter FT2, as described in connection with Fig. **12**. When the subscriber's line is looped, the current flow through resistor R1 causes rectifier QB to conduct and rectifier QA to become high resistance, and hence to cause signal current to be transmitted on the transmit channel. In this way call, dial and clear signals on originated calls and answer and clear on terminating calls are signalled into the switches.

For ringing the subscriber's bell and operating his meter, two different super-audio signal frequencies are used. The filter FR2 is terminated in two series-tuned circuits, each tuned to one of the signal frequencies and producing a voltage magnification sufficient to control a cold-cathode gas discharge tube from the low-voltage received signal. The subscriber's bell is rung by a signal frequency to which TC1 is tuned and produces on the primer of the cold-cathode tube GT1 an A.C. voltage the maximum positive value of which is sufficient to fire the tube. Tube GT1 has in its anode the primary winding of the transformer T2 and is supplied with current from a 17 c/s source, on the positive half-waves of which the tube GT1 will fire if the primer is sufficiently positive, and on the negative half-waves of which the tube GT1 will extinguish. Hence, on receipt of a ringing signal, the tube GT1 will conduct during the greater part of each cycle from the 17 c/s source; the fact that the tube will be extinguished for part of the cycle means that the ringing will cease when the ringing signal operating on the primer ceases. The secondary windings of the transformer T2 communicate 17 c/s ringing to the subscriber's line. The capacitors C1 and C2 may resonate with the transformer inductance to the ringing frequency to increase the efficiency of the arrangement. The subscriber's meter is similarly controlled and operated by an A.C. meter signal of different frequency from the ringing signal and which operates gas tube GT2, the anode circuit of which contains the meter and is fed from a 50 c/s supply. In this manner the subscriber's bell can be rung and his meter operated by equipment, within the exchange, which sends out A.C. signals at low power, operation by voice currents from the line AB being prevented by the filters.

The example given in Fig. **13** is a relatively complicated and expensive solution to the problem of the subscriber's equipment. It can be simplified if the

selectors can transmit a D.C. signal, or if separate signalling and speech paths through the switches are provided. The important point is to show that subscriber action signals can be transmitted through the switches as well as speech currents. It is not then difficult to imagine a complete system consisting of subscribers' lines, and ranks of switches in series, over which connections can be set up and controlled, and speech paths provided from subscriber to subscriber, or from subscriber to operator. The way in which the controlling signals may cause the required connections to be made is a separate study.

Conclusion.

It has been shown that automatic exchange speech path switches can be provided by element switches using any means of making and breaking a speech channel, together with either multipling or multiplexing the element switches, and that controlling signals can be generated, transmitted through the switches and caused to perform required controlling functions at a receiving point. These features are essential to any fully electronic system; the future of fully electronic systems depends very largely on the cost, complexity and reliability of the means adopted to provide these features.

Book Reviews

" Electronic Circuits and Tubes," by the War Training Staff of the Cruft Laboratory, Harvard University. McGraw-Hill Publishing Co., Ltd., London. 948 pp. 45s.

This book has been prepared from the lecture notes of a special wartime training course given in the Graduate School of Engineering, Harvard University. It was originally intended to publish the entire lecture material in a single volume, but because the single volume would have been inconveniently large, and also because a portion of the manuscript was completed early, that part has been published in a separate volume entitled " Transmission Lines, Antennas and Wave Guides." The present volume is intended as an introduction to the volume published earlier. Eleven of the original twelve members of the wartime lecturing staff are authors of the present work.

There are in all twenty-four chapters and four appendices. The first nine chapters deal with A.C. theory, impedance matching, coupled circuits, filters and Fourier analysis. The next eight deal with valves, amplifiers, oscillators and power supplies, all using valves of the normal type and not those associated with radar and wave guide techniques. Six chapters deal with modulation, detection and radio receivers; here again the frequency range of the equipment discussed is limited and is concerned almost entirely with receivers of conventional types. The final chapter deals very thoroughly with timing circuits such as those used in radar. The appendices review Mathematics and Electricity and Magnetism.

One would have expected a volume dealing with electronic circuits and tubes to have dealt with the circuits and tubes normally associated with radar and wave guides, but it does not. There is only one brief reference to a magnetron and apparently no reference whatsoever to the other types of valve which are used at frequencies suitable for wave guides.

Although much is left out and the book suffers from different styles due to the numerous authors, the work is very thorough. There are several typographical errors, the most noticeable being the repetition of Fig. 4.1 of Chapter I as Fig. 4.1 of Chapter II.

The book is stated to be for juniors and seniors of colleges and engineering schools, but it is considered to be of more use as a book of reference for those parts of the subject which are dealt with so thoroughly.

H. T. M.

" An Introduction to the Theory and Design of Electric Wave Filters." Second Edition. F. Scowen, B.Sc., A.Inst.P. Chapman & Hall, London. 188 pp. 70 ill. 18s.

The design of electric wave filters is a very complex subject, and it is impracticable to incorporate, in a book of modest dimensions, all the more advanced techniques and finer points of design; these, indeed, are hardly likely to become working tools of any but the specialist. Yet there is much that the non-specialist communication engineer can do in preparing his own filter designs, and it is for this purpose that the present book was written. The author has had considerable design experience at the Post Office Research Station, and his book, which is concise and clearly written, should be at the elbow of all engineers who wish to produce workmanlike designs for themselves.

Despite the more recent contributions of workers such as Cauer, Bode and Darlington and the high degree of precision which they have made possible, it is a fact that most practical designs are even now based on the work of Zobel, published in 1923. The underlying principles of Zobel's methods and many practical hints in their application form the main subject matter of the present book. There is no need for flights into the realm of advanced mathematics to absorb all that is necessary for " bread and butter " designs, and the necessary introduction to complex numbers and hyperbolic functions is amply covered in the first chapter; this is followed by an introduction to the necessary basic electrical theory. A chapter is devoted to practical hints on construction and includes much useful information on the properties of component reactors as well as on the methods of measurement and adjustment of both components and complete filters.

The main additional feature of the new edition is an introduction to the design of filters on an insertion-loss basis, to which Darlington has made major contributions. Although the author has done much to present the problem and some of the means of solution in a simplified form, this, in the reviewer's opinion, must be regarded as a contribution to the general education of the student rather than as extending the design facilities available to the non-specialist engineer. At the present stage of the art, at least, design on an insertion-loss basis is a job for the specialist.

R. J. H.

Local Line Plant: Pair Appropriation Records

A. MORRIS, A.R.C.Sc., D.I.C., Wh.Ex., M.I.E.E., and W. H. DOLAN, B.Sc.(Eng.), A.M.I.E.E.†

U.D.C. 621.395.743.003.3

The basic purpose of engineering records of cable pair terminations is to facilitate circuit routing and maintenance. Such records, nowadays, display much additional information in the form of code markings, which is necessary for the operation of an elaborate provision-of-service procedure as followed in the Post Office system. Accuracy and adequacy are of extreme importance, and since waste of effort would result from omissions and errors, field tests are being made of a number of different record procedures to determine the sources of potential errors.

Introduction.

WHILST post-war years have seen an exceptional increase in the number of telephone subscribers, the demand for service continues at a very high level. Restrictions on capital expenditure have limited the local line plant expansion necessary to meet such a demand satisfactorily, and the large addition to the number of working lines has been achieved only by depleting the spare plant. Whereas the number of distribution points increased approximately from 343,000 at December 1939 to 434,000 at September 1949, the percentage closed to service-extension rose from 17 to 31 per cent. over this period. The development of two-party shared service and the cabinet and pillar system of local line layout have served, to some extent, to offset the unsatisfactory spare plant position, but the present demand is so high in relation to the current supply of additional exchange-to-D.P. pairs that there would seem to be no prospect of short-term improvement of the position.

Line plant cable pair appropriation cards are an essential engineering record for the purpose of noting the identity of cable pairs at their terminals. They are used for circuit routing and maintenance purposes; they also give information as to the addresses and telephone numbers of subscribers. In order to overcome the difficulties of providing telephone service at the present time, and to ensure that priority and shared service requirements are met, extensive sales machinery has been developed. Its operation is based upon an elaboration of the line plant records, which are required additionally to display considerable information in the form of code markings, relating solely to the detailed business of giving service.

The extent to which all the line plant provided in a telephone system can, in fact, be made use of and the speed with which it can be brought into service depend upon the accuracy and completeness of the spare plant records. At the same time, efficient maintenance necessitates clear and correct details of working circuits. Much attention is given to this subject in other countries and it is of interest to note that a booklet issued by an American telephone company so far back as 1927 stressed, in no uncertain terms, the great value of adequate and accurate records.

So far as the trunk plant is concerned, the importance of record work is well recognised. This is reflected in the considerable country-wide organisation, centralised at Headquarters and operated in the Regions and Areas by engineering, clerical and drawing-office staffs, which has been built up to deal with the provision of trunk circuits. In regard to local line plant, however, the equal importance of record work may not at first be apparent; particularly as such work is, of necessity, devolved to an extreme degree and is, in the main, carried out by minor staff. Furthermore, the plant cost per circuit is very much lower than that for trunk circuits. Nevertheless, the total value of the local line plant amounts to the enormous figure of £130 millions—some 50 per cent. greater than that of the trunk and junction line plant—and the routing processes in the two cases differ little in intricacy, except that whereas trunk lines in general are simple exchange-to-exchange links, local cable pairs are exchange-to-D.P. links, the latter terminals being widely dispersed territorially.

It is the object of this article to direct attention to the extreme importance of accuracy in the recording of local line plant, to emphasise the impairment and even waste of effort which would result from errors and omissions, and to stimulate an even greater interest in the work of compilation and upkeep of these records. Whilst the staff actually originating and using these records are given special training for the work, yet in present-day circumstances and in view of its importance, a statement of the problems involved will, it is thought, be of general interest.

Brief Description of Records and Routing Procedure

The following brief description of the system of records employed in the appropriation of local cable pairs in this country will be helpful in the later discussion of the general subject. Particulars of the terminations of working pairs in subscribers' cables and of the availability of spares constitute the essential basic information for the provision and maintenance of telephone service. A simple, direct and complete record system is desirable. A standard method of card recording is employed throughout the country, and considerable study has been given post-war to the development of records for the cabinet and pillar system of plant layout. The cards are held at Installation Controls and are used there by Routing Officers in the general day-to-day business of circuit routing and provision of service. A typical Installation Control is shown in Fig. 1.

For a D.P. connected direct to the exchange, the exchange and D.P. terminations of all cable pairs from the D.P. are given on one card designated the

† Mr. Morris is Staff Engineer, Local Lines and Wire Broadcasting Branch, Engineer-in-Chief's Office and Mr. Dolan, Executive Engineer in that Branch.

FIG. 1.—A TYPICAL INSTALLATION CONTROL.

addition, the choice is made so as not to impair the chances of being able to use pins for the subsequent connection of the remaining pairs. These objects are best achieved by examination of all three cards jointly. The cards when laid out side by side (with the D.P. card on the left) present a clear picture of the various possible ways of making the selection.

The sequence of use of cards for all routing purposes is from D.P. to the exchange and a number of examples of the use of the cards for various layouts of plant are shown in Fig. 3.

Particulars of the principal cards employed in connection with cabinet and pillar layouts are as follows :—

Card Description	*P.O. Code*	*Size*
D.P. card	A2555	8 in. × 5 in.
Branch Cable card	A2550	Demi-Quarto
Main Cable card	A2549	Demi-Quarto

" D.P. card." This card also exhibits information relating to shared service connections as well as elaborate markings required in connection with the present-day joint sales and engineering organisation for provision of service. The card is shown in Fig. 2.

The appropriation of pairs in subscribers' cable networks involving cabinets and pillars is normally made on three cards which show the relationship between the terminals of the distribution, branch and main cables, and are known as " D.P.," " Branch Cable " and " Main Cable " cards respectively. Additional cards are employed for indexing and for the recording of multiple-teed cable pairs and link-cable pairs.

The procedure for allocating pairs for circuit provision will depend on whether pairs have been pre-pinned or pre-jumpered at cabinets and pillars. It is envisaged that ultimately the bulk of cable pairs will have been so arranged, and in that event allocation is a relatively simple process ; a spare pair is traced through from the D.P. card via the Branch and Main Cable cards to the M.D.F., the circuit number or reservation symbol R then being entered on all three cards. Where circuit provision is dependent on the selection and connecting together of pairs in the distribution, branch and main cable networks, the pairs are selected so that bridging-pins rather than jumpers can be used for setting up the circuit ; this applies particularly to cabinets where jumpering capacity is limited. In

D.P. CARD — Pillar No. 4/2 — Exch. BLANKTOWN — D.P. No. 101 — W — A2555 (LINES, Dem. Amid)

S. Ref. No. 6 — D.P. Address 1, NEW STREET

Type of D.P.: Open Wire, Armed — Survey required — No. & Type of Terminations: 15 B.T. No. 9 — D.P. Cable: Pairs 15, Weight 6½ — Minimum Spares: 3, 15/50, 1.4.50 — Distribution Cable Res. Ohms: 46

*Delete as necessary

D.P. Pair No.	Pillar 'Term' No. 'D' Side	'E' Side	Ex.	Subscriber's Record, etc. Circuit No.	Name	Address	X 'Conn' to D.P. No.	X 'Conn' to Pillar No.	Subs. Agreement
1	51	51		3222 Y	SMITH H.	8, NEW STREET			PP
2	52	52		3567 X	ROBINSON F.	28, NEW STREET			PP
3	53	53		A 17 4 50		236, HIGH STREET			
4	54	54		9691	JOHNSON C.	RED LION HOTEL, HIGH STREET			
5	55	15		3322	Mc DOUGALL & Co	240, HIGH STREET			
6	56	16		5412 X	DONOVAN J	21A, NEW STREET			PP
7	57	29		R	FLOWERS T.	242, HIGH STREET			
8	58	6		3863 X	BLACK G	1, NEW STREET			PP
9	59	31		9682	JOHNSON C.	RED LION HOTEL, HIGH STREET			
10	60	69		3322 EXTN 1	Mc DOUGALL & Co.	240, HIGH STREET	81	4/1	
11	61	14		8305	SCOTT P.	5, NEW STREET			
12	62								
13	63								
14	64								
15	65								

Workmen (1940) Wt. 26457 100m (a) 1/40 Gp.497 O.B.A.Co.Ltd.

EXCHANGE BLANKTOWN — D.P. No. 101 — Other D.P.s on same PILLAR, D.P. No.

PILLAR No. ..... Address .....

CABINET No. ..... Address .....

Subs. No.* of Line to which Teed (from other side)	PARTY LINES TEED to Circuits in Col. 1 — Subs. No.*	Name	Address	D.P. No.	Location of Tee	Subs. Agreement
5412 X	2475 Y	BROWN, C.	21, NEW STREET	101	Subs lead in	PP
3567 X	2967 Y	GREEN F.	16, NEW STREET	101	Pole 1	PP
3863 X	3528 Y.	JACKSON H.	108, HIGH STREET	101	DP	PP
3222 Y	2481 X	COPLEY L.	3, NEW STREET	101	DP	PP

* Insert X or Y as appropriate after each Subs. No.

FIG. 2.—D.P. CARD, FRONT AND BACK.

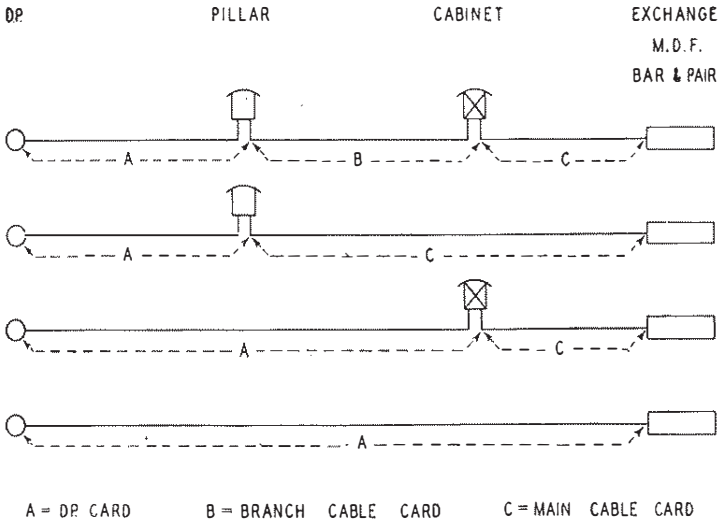


FIG. 3.—USE OF CARDS FOR VARIOUS LAYOUTS OF PLANT.

Code Markings.

In addition to details of the termination and jumpering of cable pairs, and the circuit numbers and addresses of working subscribers, the D.P. card now displays service provision information, in the form of code letterings. For example, a subscriber who accepts service knowing that he has an obligation to share his line is marked as a Potential Party subscriber, the letters P.P. being entered in the column provided for that purpose on the D.P. card. The extent of such service provision markings of cards can be gathered from the following list :—

- P.P. A subscriber who by the terms of his agreement is liable to accept shared service.
- W.P.P. A subscriber who has been given exclusive service without agreeing to share, but has been warned that his agreement will be terminated if he refuses to share when called upon to do so. [This code is now discontinued.]
- R. Reservation of pair for applicant.
- R.E. Reservation of pair for a probable essential applicant.
- W. Indication of the existence of waiting applicants at the D.P.
- A. Advice has been given to Sales Division that a spare pair or sharing facility is available.
- X. Shared service installation at which ringing is effected without wiring changes to the multiple or calling jack at the exchange.
- Y. Shared service installation at which wiring reversals to the multiple or calling jack at the exchange are required for ringing.

NEED FOR ACCURACY

Before dealing with the circumstances which lead to errors in recording, and prior to the discussion of means for preventing such discrepancies, the magnitude and significance of the broad issues involved in the matter of adequacy and accuracy of line plant records need to be considered.

Numerical Values Involved.

The value of the local line plant identified on card records is of the order of £130 millions (as at 31/3/49), the value of underground plant being approximately three times that of overhead plant. Approximately, the number of working lines is 3·4 millions and the number of spare pairs through from D.P.s to exchanges is 1·1 millions. As a broad average, therefore, the capital value of a pair from a D.P. to the exchange is £29. Now the number of D.P. cards involved is approximately 434,000 and therefore an error involving the "loss" of one cable pair in 200, i.e. one lost pair per 20 D.P.s on an average, would result in a potential capital loss of £0·65 million.

Waiting List and Spare Line Plant.

With the continuing heavy demand for telephone service, and in spite of the fact that more than a million telephones have been added to the system since the end of 1945, the present waiting list stands at approximately half-a-million, of which some 350,000 are awaiting line plant.

The worsening of the position in respect of availability of spare pairs from June 1944 to September 1949 for the country as a whole is shown in Table I.

TABLE I

Total number of D.P.s serving U.K. telephone subscribers and their condition in regard to spare pairs, at various dates.

Date	30 June 1944	30 June 1945	30 June 1946	30 June 1947	30 June 1948	30 Sept. 1949
Total No. of D.P.s	372,975	376,721	384,576	397,224	414,300	433,808
Percentage of Total D.P.s with not more than 25 per cent. spares ..	47	49	54	61	62	61
Percentage of Total D.P.s with no spares	23	23	28	33	34	31

In such circumstances, errors in records which involve the "loss" of cable pairs would be intolerable. An overall error in records involving ½ per cent. of the total through cable pairs from D.P.s to exchanges would result in a " loss " of approximately 22,500 pairs in the country as a whole.

Efficiency of Utilisation of Plant.

The efficiency of utilisation of plant can be considered from two aspects. Firstly, long-term considerations demand that all pairs, between D.P.s and the exchange, provided under development schemes, should be available for use when required.

Secondly, speed in the assignment of available facilities is essential for the smooth running of the provision-of-service organisation. In so far as long-term utilisation efficiency is concerned, the matter resolves itself into economic considerations of a similar nature to those employed when the plant was originally provided.

The pernicious effects of errors in D.P. cards and other records, in so far as day-to-day provision of service is concerned, cannot be over-estimated. In the present circumstances of plant shortage and pressure of demand for service, it is imperative that the information passing between Sales and Engineering organisations should be correct. If a spare service facility were shown as available on the records, when in actual fact it did not exist, the subsequent furnishing of incorrect advice to the applicant might result in a commitment to provide service at considerable expense. The interchange of information between Sales and Engineering Divisions in relation to the provision of shared service is considered subsequently.

Planning.

Whilst care has been taken to ensure as simple a system as possible, the records required for cabinet and pillar layouts are necessarily more detailed and extensive than those hitherto employed. In addition, the multiple-teeing of cable pairs in main and branch cable networks has necessitated the introduction of special records. As a consequence, more attention and effort is involved in maintaining a high standard of accuracy.

The planning of new development schemes is based upon card records relating to the working and spare components of the existing plant. It is obvious that the field staffs would experience difficulty in the execution of the planned work if errors were carried forward into the cable pair jointing and diversion schedules. A severe restriction would be imposed upon local line development planning if little or no reliance could be placed upon cable pair appropriation records; detailed jointing and diversion schedules could not then be made. Errors in the records would give rise to differences between the number of cable wires actually changed over and the number estimated. In such circumstances, planning could only be carried out on a broad basis; departures from estimate upset the planned stores-to-labour ratio, and close budgetary control would become impossible.

Shared Service.

The procedure for the provision of two-party shared service is largely based upon and necessitates an extension of scope of the engineering record machinery. The various code markings which, in this connection, are entered on D.P. cards have already been listed. In order to meet the circumstances brought about by the acute shortage of plant an involved provision-of-service procedure is necessary to ensure the interchange of all necessary information between Sales and Engineering Divisions. The omission of a marking from the D.P. card may result in Routing Officers being unable to advise Sales staff of the facilities for providing telephone service. For example, if one subscriber only at a particular D.P. with no spares is marked P.P., an enquiry as to whether service can be provided at the same D.P. can be dealt with as—"Spare Sharing Facility Available." Unless a special survey was undertaken, absence of the P.P. marking would result in incorrect information being given as to the actual service facilities available.

Spare Plant Return.

A revision of the procedure for recording spare pairs in subscribers' cables has been necessitated by the introduction of flexibility based on cabinets and pillars. These have the effect of sub-dividing local cable systems into three sections, namely the main, branch and distribution networks. The old return provided complete information respecting spare pairs through from D.P. to exchange M.D.F. on one record, whereas the revised return which will make its first appearance in September, 1950, will provide information as to the spare position in each section of the network. The return will be derived from the cable pair appropriation records, and its primary object will be to provide a check on the adequacy of plant in the various sections of the network. As a secondary function the return will provide data for Regional control purposes and for statistical requirements at Headquarters.

Because of present-day restrictions on capital expenditure, the spare plant position, which is a major factor in deciding the question of augmentation, has to be carefully assessed. This will be assured only if the fundamental information provided on the cable pair appropriation cards is complete and accurate.

Sources of Error

There are many paths by which errors can be conveyed to records and it is necessary to consider them in some detail. Firstly, errors may be introduced in the initial preparation of records due to clerical error or due to errors in the cable pair jointing schedules from which the records are compiled. During its life the information contained on a card record is continually changing due to the addition of new subscribers, recoveries, codings for provision of service conditions, etc. Errors may arise from an inadequacy of information or from a failure to record the details supplied.

The interchange of information between Sales and Engineering Divisions during the day-to-day business of providing telephone service makes it necessary that the information incoming for record purposes should be complete and accurate. Furthermore, the efficient team-working of field and record office staffs has to be promoted by a mutual understanding of the difficulties caused if, for example, a cable pair other than the one assigned were taken to give service to a new subscriber.

Duplication of records is most undesirable as any differences in the details recorded increase with time up to a stage when neither can be relied upon

as accurate. Indifferent attention to neatness and legibility when entering information on cards will lead to errors, as also will failure to ensure that cards are kept in good condition in suitable accommodation.

War damage to local line plant and improvisation of plant to meet war conditions have of themselves led to unavoidable errors in records in this country, and estimates of the accuracy and completeness of post-war records varies widely between Telephone Areas. War repairs to cables have led to not inconsiderable errors despite the steps taken at the time to locate and identify cable pairs in the field; active steps have also been taken in post-war years to find "lost" pairs. It will be appreciated that where there is doubt as to the accuracy of the records, numerous checks, by way of survey work in the field, may be necessary.

Field Trials

The detailed methods employed in the preparation and maintenance of records in any Area will depend to some extent on the organisation existing in that Area for local line plant planning, provision and maintenance. In order to assess the relative merits of differing organisations in so far as final record accuracy is concerned, and to identify the major sources of record errors, experiments are being undertaken in the Glasgow, Peterborough, and Reading Telephone Areas. An investigation will be made in each Area to check the accuracy and completeness of information forwarded to Installation Controls for entry on local cable pair appropriation records, i.e. sample checks of recorded information shown on Advice Notes, Diversion Schedules, and Jumper Connections at M.D.F.s will be made against the actual conditions in the field as shown by physical inspection of the plant. Sample checks of records after the replacement of faulty lengths of cable will also be included.

At the end of the experimental period, a return for each Area will be prepared which will show the numbers and percentage of errors and where these errors were located, i.e. in Advice Notes, Diversion Schedules, etc. It is hoped that this information will assist in the determination of any remedial measures considered necessary.

Conclusion.

Engineering cable pair records are nowadays augmented by extensive information in the form of code markings which are necessary to the present Sales procedure for providing telephone service (including shared service). In addition, the form of the record has been modified to suit the modern plant layouts resulting from post-war developments in local line planning methods. It is essential, therefore, that in the present circumstances of acute shortage of line plant, all staff concerned with records should have a clear appreciation of the part records play in the present-day business of providing telephone service and of the importance to be attached to the need for adequate and accurate records. It is obviously in the interests of the officer holding the record or supplying record information not to make clerical errors; likewise, it is in the best interests of an engineering officer in the field that he should never appropriate a spare pair on his own initiative, when a call to the record officer would secure a pair which would be marked as assigned.

Adequacy and accuracy in local line records can only be achieved by consideration being given to all aspects of the matter of routing pairs for telephone provision and maintenance purposes. Accommodation for staff, type of staff, training of field staff in a knowledge of, and appreciation of, the importance of records are but a few items which necessitate the continued active interest of the staff concerned with the telephone service.

TELEGRAPH AND TELEPHONE STATISTICS—SINGLE WIRE MILEAGES AS AT 31 DECEMBER, 1949.
POST OFFICE MAINTENANCE—EXCLUDING SUBMARINE CABLE.

REGION	OVERHEAD			UNDERGROUND		
	Trunks and Telegraphs	Junctions	Subscribers*	Trunks and Telegraphs†	Junctions‡	Subscribers¶
Northern Ireland	6,158	6,500	38,412	114,621	47,336	147,421
Scotland	11,852	27,190	218,552	819,671	341,624	932,135
Home Counties	366	11,715	388,379	2,030,801	600,277	1,568,324
Midland	1,652	19,269	242,510	1,145,773	364,371	1,125,416
North Eastern	2,395	12,174	208,536	926,712	360,792	1,109,428
North Western	830	5,785	124,379	733,912	420,978	1,318,039
South Western	1,257	21,179	299,878	1,054,511	224,382	867,994
Welsh and Border Counties	2,742	16,097	168,471	529,753	142,342	361,777
Provinces	27,252	119,909	1,689,117	7,355,754	2,502,102	7,430,534
London	—	416	88,329	1,077,955	2,286,926	4,130,129
United Kingdom	27,252	120,325	1,777,446	8,433,709	4,789,028	11,560,663

* Includes all spare wires. † All wires (including spares) in M.U. Cables. ‡ All wires (including spares) in wholly Junction Cables.
¶ All wires (including spares) in Subscribers' and mixed Junction and Subscribers' Cables.

Design of Square-Law Rectifier Circuits for Measuring Instruments

D. C. WALKER, B.Sc.(Eng.), A.M.I.E.E.,
D. L. RICHARDS, B.Sc.(Eng.), A.M.I.E.E.,
G. P. HORTON, B.Sc.(Eng.).†

U.D.C. 621.314.6 : 621.317.7

The peak/root-mean-square ratio of speech waveforms may be as great as 11 db. or even more, so that a meter which is required to give accurate r.m.s. indications must be capable of handling an instantaneous input level well above that of a steady sine wave giving the same meter reading. A range of at least 16 db. is required over which the meter must conform to a square law. This can be achieved using a rectifier circuit connected to a D.C. moving-coil instrument by the novel principle of using rectifier discs in combination with series and shunt resistors. Three rectifier circuits are described which have been used in equipment for measuring noise or speech levels. An accuracy of about ±0·3 db. has been achieved in measurements where practical waveforms are concerned.

Introduction.

MANY measurements of alternating quantities require the use of an instrument which will give a true r.m.s. indication. If attention can be confined to sinusoidal waveforms almost any form of meter can be used provided it is suitably calibrated. For example, peak-reading or linear-rectifying thermionic voltmeters are commonly calibrated so that correct r.m.s. indications are given for a sinusoidal input. If a complex waveform such as noise or speech is to be measured it is often desirable to express the results of measurements as r.m.s. quantities and an accurate square-law meter is then necessary.

When the highest frequency of a component having appreciable magnitude is not greater than a few hundred cycles per second, moving-iron or electrodynamic instruments are suitable. Moving-iron meters are being developed for use at audio frequencies up to a few thousand cycles per second but none is yet available. Accurate measurements of complex waveforms may be made at almost any frequency by means of a thermo-couple meter. Such a meter is stable and reliable provided it is used carefully, but suffers from liability to damage by accidental overload. This is a particularly troublesome feature if the r.m.s. value does not remain constant over a period, say, of ten seconds, sufficient to take a reading.

Where speech or variable types of noise are concerned the r.m.s. value of the waveform is a function of time and also of the interval over which the waveform is integrated (integration period). The integration period of a thermal meter is controlled mainly by the thermal capacity of the couple element and cannot be reduced below a value of a few seconds. The integration period may be defined as that duration for which a steady input must be applied to ensure that the meter gives a maximum indication 2 db. lower than the indication which would result were the same steady input applied indefinitely.

The measurement of speech or noise levels (either acoustical or circuit noise) requires the use of meters having integration periods of the order of a few hundred milliseconds. This excludes the thermal type of meter. Thermionic valve circuits are available[1,2] which enable an adequate range of square-law characteristic to be obtained but these all suffer from the necessity of setting the zero of the indicating instrument. If i is the instantaneous current through the D.C. milliammeter and v is the applied input voltage, the characteristic of a valve circuit could be $i = A + Bv^2$ over a sufficient range of v, where A and B are constants. The zero setting is necessary to balance out A. A rectifier-type meter (i.e. a metal rectifier network followed by a D.C. moving-coil milliammeter) offers very many advantages and rectifier networks can be designed to have the characteristic $i = Bv^2$ over a limited but sufficient range of v.

The waveform of speech and of many common types of varying noise is such that the peak instantaneous values of a speech or noise voltage are 4 to 6 db. higher than the voltage corresponding to the r.m.s. reading given by a meter having an integration period of 0·1 second (e.g. speech voltmeter). If the comparison is made with a r.m.s. meter having an integration period of more than about two seconds the peak/r.m.s. ratio may be as much as 11 db. These ratios are even greater when the speech circuit uses a carbon granule transmitter. This wide range of instantaneous values relative to the r.m.s. indication makes it necessary that the square-law characteristic of the rectifier network holds accurately over a correspondingly wide range. With 0·1 second integration period, a range from 5 db. below the normal r.m.s. reading to 11 db. above it is desirable. Over this range the instantaneous current should not depart from its correct value by more than 10 per cent. For a long-integration-period meter a total range of some 40 db. is necessary if r.m.s. indications of speech waveforms are to be obtained accurately.

Basic Square-law Circuit with Metal Rectifiers

The basic circuit for square-law rectifier networks is shown in Fig. **1**, where R_1 represents the source and meter load resistance and R_2 a rectifier-shunting resistance. For practical applications, however, the circuit used would be of the full-wave type, probably employing a bridge network. Only the forward direction of the rectifiers will be considered and for this direction the current/voltage characteristic of a typical cuprous oxide metal rectifier (actually the Post Office C-type, ¼ in. diameter disc) is shown plotted to logarithmic scales as curve (3) in Fig. **2**. It will be seen that the slope is steeper than that corresponding to a square-law over most of its range, and only

† Engineers, Research Station.

[1] Harbottle, H. R. "The Circuit Noise-meter (Psophometer) and its Applications," *J.I.E.E.*, Vol. 83, p. 261 (1938).

[2] Ross, H. McG., and Shuffrey, A. L. "An Electronic Square-Law Circuit," *J.Sc. Inst.*, Vol. 25, p. 200.

approximates to that of a square-law over small ranges around 10 μA and 10 mA. Increasing the diameter of the discs has the effect of moving the

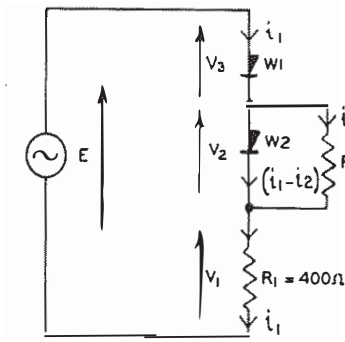


FIG. 1.—BASIC CIRCUIT OF SQUARE-LAW RECTIFIER NETWORK.

characteristic curve bodily upwards along the current axis, while connecting several discs in series shifts it to the right. The slope of the curve can only be reduced by combination with resistive elements—for instance, series resistance (including source and load impedances) modifies the characteristic at high currents. Changes can also be effected at lower currents by the novel principle of using several rectifier ele-

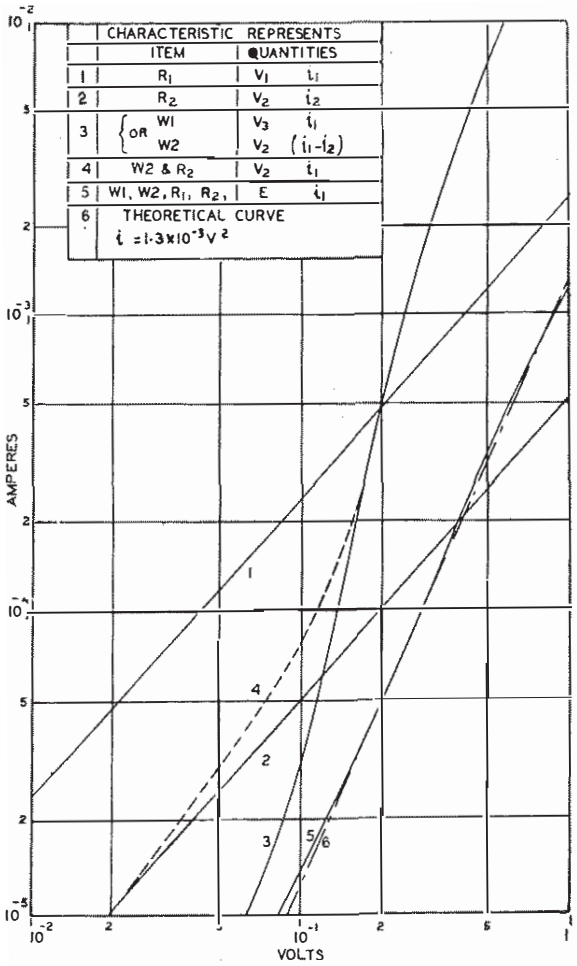


FIG. 2.—GRAPHICAL SYNTHESIS OF BASIC SQUARE-LAW RECTIFIER NETWORK.

ments in series and shunting some by resistors. Such a scheme was first developed in 1942 for use in a psophometer.

The function of each component of the circuit shown in Fig. **1** will be made clearer by a graphical synthesis of the characteristic for this simple case. Thus, in Fig. **2** curves (1), (2) and (3) represent, respectively, the current/voltage characteristics of R_1, R_2 and W1 or W2. By adding the current ordinates of curves (2) and (3) curve (4) is obtained which represents the characteristic of W2 and R_2 in parallel. Thence by adding the voltage abscissæ of curves (1), (3) and (4) the current/E.M.F. curve (5) is arrived at; this coincides reasonably well with the true square-law characteristic of curve (6).

The above example illustrates how R_1 and R_2 control the shape at opposite ends of the characteristic and this fact facilitates their choice in trial designs. In practice they may require slight adjustment after assembly to achieve the characteristic desired.

TYPICAL CIRCUITS

Psophometer Detector.

One example of this rectifier network is shown in the psophometer detector circuit in Fig. **3**. The output valve is triode-connected and voltage feedback is applied over the two amplifier stages to obtain a low output impedance—the transformed impedance presented to the rectifier being about 200 ohms. The meter has a full-scale deflection of 100 μA but it is calibrated with a square-law scale. For convenience the rectifier bridge is type MBH 4-3-1 (P.O. C-type, $\frac{1}{4}$ in. diameter discs in a moulded bakelite case which permits extra tags at the junction of each pair of rectifier elements).

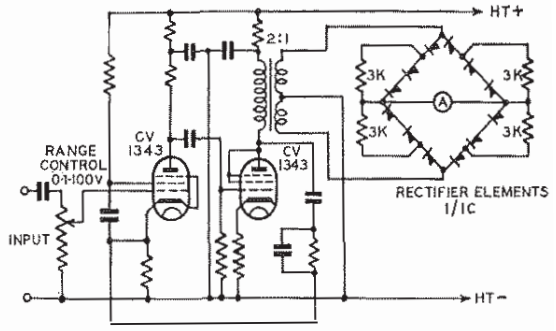


FIG. 3.—AMPLIFIER AND RECTIFIER CIRCUIT OF PSOPHOMETER.

The waveforms of noise which a psophometer is required to measure necessitate a reading accuracy of ± 5 per cent. for a sinusoidal input voltage from 0·4 to 2·5 times that required for full-scale deflection. Thus the direct current/r.m.s. A.C. input voltage (sinusoidal waveform) characteristic must be measured over an extended range, i.e. at least 1/6 to 6 times full-scale current—to check its deviation from a square-law. This entails using a special D.C. meter circuit with variable sensitivity but constant resistance.

Speech Voltmeter.

It is not necessary that the rectifier circuit should be arranged in bridge formation. If a double winding

(or a centre tap) is provided on the transformer feeding the circuit, an increase in efficiency is possible by using a bi-phase arrangement. Such an arrangement is used in the P.O. Speech Voltmeter Type 3 and the essential elements are shown in Fig. 4. Although

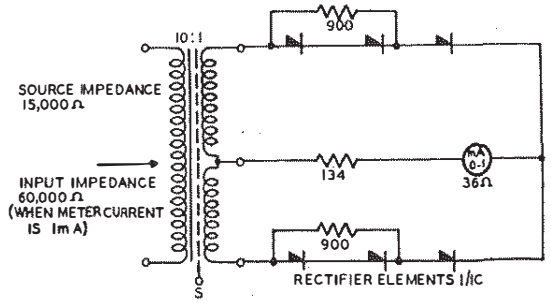


FIG. 4.—RECTIFIER CIRCUIT OF SPEECH VOLTMETER.

the type of rectifier discs is the same as in the psophometer, the use of a 1 mA indicating instrument necessitates different values of series and shunt resistors.

The speech voltmeter circuit enables the true r.m.s. voltage of a wave having the level distribution of speech[3] to be measured with an accuracy not worse than ±0·3 db. provided that readings are made at a deflection between −3 db. and the upper limit of the scale (+3 db.). This assumes that the speech voltmeter has been correctly calibrated using a sinusoidal input at, say, 1,000 c/s.

Speech Analyser.

A speech analyser recently constructed by one of the authors[4] employed an integration period of 15 seconds, which may be increased to 60 seconds if required. The square-law circuit developed for this analyser is similar in principle to that employed in the psophometer and speech voltmeter and is shown in Fig. 5. To achieve the range of 40 db. it was necessary

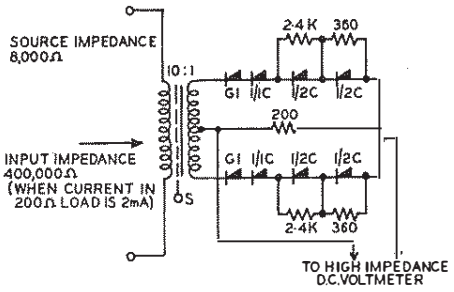


FIG. 5.—RECTIFIER CIRCUIT OF SPEECH ANALYSER.

to use more elements, as well as two different sizes of cuprous oxide disc. Fig. 6 shows the current/voltage characteristic, indicating that, over a range of 40db., the current is within ±20 per cent. of the correct value. (This corresponds to an accuracy for instantaneous inputs of better than ±1db.)

Calculation of the error introduced by this circuit under working conditions shows that, over a range of r.m.s. speech input level of 10 db., the error does not amount to more than ±0·25 db. If the equipment is calibrated using a sinusoidal input at a level differing

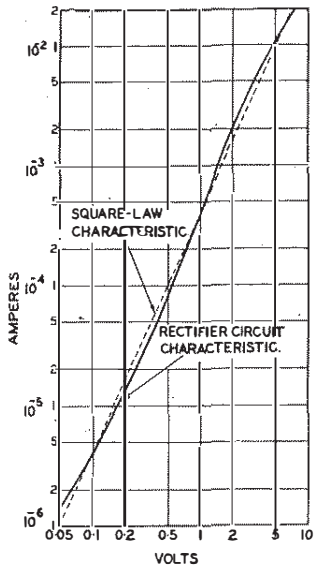


FIG. 6.—CURRENT/E.M.F. CHARACTERISTIC OF RECTIFIER CIRCUIT OF SPEECH ANALYSER.

considerably from the r.m.s. speech level, an additional error of not more than ±0·25 db. is introduced.

In general, however, it can be arranged that calibration is carried out at a level within ±5 db. of the r.m.s.speech level so that the total error is unlikely to exceed ±0·3 db.

PERFORMANCE OF SQUARE-LAW RECTIFIER CIRCUITS

The usefulness of a square-law rectifier circuit depends, in practice, upon further factors than the possible accuracy of the static characteristic (instantaneous current/voltage relationship). It is important that the characteristic should be realisable without extreme care being necessary in the selection of rectifier discs and that the characteristic, once obtained, should remain constant under practical conditions. These features, together with the upper frequency limit, are discussed below. These effects apply ahnost equally to the three types of square-law rectifier circuit described above.

Selection of Discs.

Current/voltage characteristics measured on a sample of C-type discs show a fairly wide variation. The resistance limits (measured at 1 mA) to include 90 per cent. of individuals in one particular sample were 220 to 245 ohms at 20°C. The shapes of the several characteristics, however, are almost identical and can be superimposed, when plotted to logarithmic scales, by a linear change along the current axis. Typical curves are given in Fig. 7. This property of the characteristics enables matched sets of discs to be selected at a single value of current. Assembly of rectifier circuits is also simplified because, over the range of variation of individual characteristics which occur, circuits composed of matched sets of discs

[3] Dunn, H. K., and White, S. D. "Statistical Measurements on Conversational Speech," *Journal of the Acoustical Society of America*, Vol. 11, p. 278 (1940).

[4] "A Speech-Spectrum Analyser," *P.O.E.E.J.*, Vol. 41, p. 188 (1949).

differ very little in the accuracy with which they conform with a square-law. Some variation (amounting to about 1 db.) in absolute sensitivity occurs but this can easily be compensated by adjustment of the gain of the preceding amplifier. This conclusion is not quite true of the more complicated speech analyser circuit where some selection of the G-type disc is always necessary.

Effect of Temperature.

Temperature change affects the individual current/voltage characteristic of rectifier discs in such a manner that the whole characteristic is moved along the current axis with little change in shape, as shown in Fig. 8. The effect of temperature on the overall

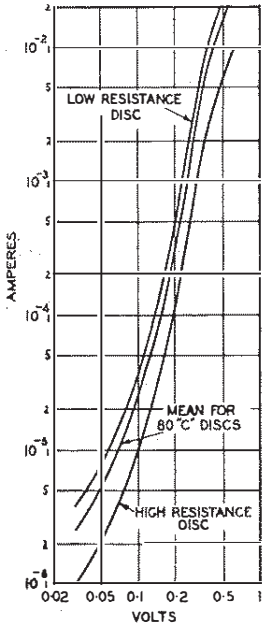


FIG. 7.—TYPICAL RANGE OF CURRENT/VOLTAGE CHARACTERISTICS OF "C" TYPE DISCS.

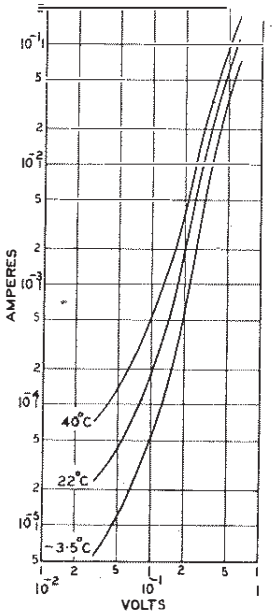


FIG. 8.—EFFECT OF TEMPERATURE VARIATION ON CURRENT/VOLTAGE CHARACTERISTICS OF "C" TYPE DISCS.

characteristic of the complete square-law circuit, furthermore, consists mainly of a change in absolute sensitivity with little change in the range of conformity with the quadratic law. Fig. 9 shows the effect on the complete circuit of the speech voltmeter (Fig. 4). The temperature coefficient of the complete circuit is as follows.

¼	full-scale current,	+ 0·050 db. per °C.
½	,, ,, ,,	+ 0·028 ,, ,, ,,
	full-scale	+ 0·017 ,, ,, ,,
2×	,, ,, ,,	+ 0·0083 ,, ,, ,,

This effect, although rather large, does not seriously impair the use of these circuits provided that the calibration is adjusted before use.

Effect of Reassembling Sets of Discs.

The C-type discs used are assembled in a plastic holder with pressure applied by means of a coil spring. The resistance of discs is unaffected by being dismantled and reassembled, or by a change in pressure,

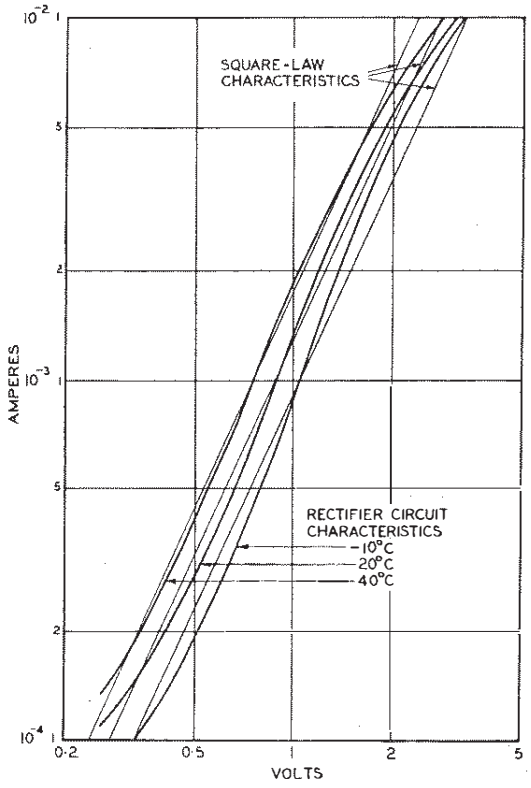


FIG. 9.—EFFECT OF TEMPERATURE VARIATIONS ON CURRENT/E.M.F. CHARACTERISTICS OF RECTIFIER CIRCUIT OF SPEECH VOLTMETER.

except for a temporary change of resistance amounting to about 5 percent. which disappears five minutes after reassembly, if the normal pressure is applied. If double the normal pressure is applied, a period of 10 minutes is required for stability to be reached.

Upper Frequency Limit.

The presence of the comparatively large self-capacitance of rectifier discs limits the use of the square-law circuits described here to frequencies not greater than about 12 kc/s. This, however, is ample for speech measurement or for measuring audio frequency noise.

The self-capacitance of a single C-type disc is of the order 2,000 pF. In the speech voltmeter where a bi-phase circuit is used the capacitance of three discs in series is shunted across the idle half of the transformer winding. This imposes a limit on the maximum leakage inductance of the transformer and some special attention is necessary in the design of the transformer. When a transformer having too great a leakage inductance is used the frequency characteristic rises to a maximum in the high frequency region. The magnitude of this effect varies with the level of voltage applied to the rectifier circuit. The leakage inductance must therefore be reduced to such a value that this rise in sensitivity occurs at frequencies beyond the range required. Similar, but slightly more complicated, effects occur in the psophometer and speech analyser circuits but the limitation of frequency range remains about the same.

A Survey of Modern Radio Valves

R. W. WHITE†, B.Sc., F.Inst.P., A.M.I.E.E.

Part 5—Valves for Use in the Range 30-3,000 Mc/s (Bands 8 and 9)

U.D.C. 621.385.1

The deterioration in the performance of normal valves at the higher frequencies is discussed, and the more important contributory factors are indicated. Desirable design features are tabulated, and some examples of the more important classes of Band 8 and 9 valves are briefly described.

Introduction.

BAND 8 of the radio frequency spectrum (i.e. 30-300 Mc/s) accommodates such diverse services as high fidelity broadcasting, television, radar, navigational aid systems, and a wide range of civil and military communications. Since triode and pentode valves operating satisfactorily over part or all of this band are now readily available, use of it has become widespread, and in the more highly developed areas of the world frequency allocation problems are already acute.

Band 9 (i.e. 300-3,000 Mc/s) offers ten times the available frequency spectrum of Band 8, but is at present relatively little used in comparison with Band 8. Usage of Band 9 has increased to a marked extent in the last decade ; but it may still be regarded as a transitional region so far as both valve and circuit technique are concerned. Few pentode valves will operate at all even at its lower limit of 300 Mc/s, but a limited number of the most advanced types of modern triodes can be used up to, or a little beyond, its upper limit of 3,000 Mc/s. In the region beyond 3,000 Mc/s, which will be covered in Part 6 of this survey, waveguide circuits are predominant, and the valves in common use are dependent on electron inertia effects for their normal operation ; but it should be mentioned here that the types of valves used for Band 10 are also made for use in Band 9. To minimise duplication, however, the present article will be concerned primarily with the development of triode, tetrode, and pentode valves for operation between 30 Mc/s and the upper limits of frequency at present realisable.

The Post Office Engineering Department uses allocations in Bands 8 and 9 for communications between fixed or mobile stations, and for repeatered relay systems. The modulation frequency band involved may range from a single telephony channel (say 300 to 3,400 c/s) through multi-channel telephony services to television systems involving frequencies up to 3 Mc/s. For Post Office applications, the main emphasis must be on valves suitable for use as stable amplifiers rather than as self-oscillators, and on continuous ratings rather than pulse conditions, while reliability and long life of the valves are of primary importance.

Electron Transit-Time.

The electron possesses a ratio of charge to mass far greater than that for any atomic or molecular particle. Thus, when an electron is placed in an electric field it experiences a force of enormous proportions relative to its mass, and by the normal Laws of Motion its acceleration is extremely rapid. Since electrons possess this extreme mobility, the operation of a valve at low frequencies may normally be regarded as instantaneous. At 100 Mc/s, however, we are dealing with signals which complete one cycle in a hundredth of a microsecond, and the time taken by electrons to traverse the inter-electrode spaces of a valve can no longer be neglected.

When a valve is operating under normal conditions of space-charge current limitation, the time of transit (t) of an electron from cathode to grid is given approximately by the relation[1] :—

$$t = 6{\cdot}6 \times 10^{-10}\left(\frac{d}{i}\right)^{\frac{1}{3}} \text{ seconds} \quad \ldots\ldots\ldots (1)$$

where d is the grid-cathode spacing in centimetres, and i is the current density in amperes per square centimetre. Thus for short transit-times, small electrode spacings and high current density are required. The latter requirement necessitates high voltages and high cathode emission.

In V.H.F. valves, finite electron transit-time leads to three main disadvantages. Firstly, the mutual conductance is decreased in magnitude and is made a complex quantity by the introduction of a phase angle varying with frequency and with changes in the applied voltages. Secondly, an input shunt resistance is introduced which varies approximately as the inverse square of the frequency, and as the inverse square of the cathode-grid transit time. Thirdly, increasing transit-time reduces the anode efficiency realisable in a power amplifier or oscillator. These effects lead to reduced operating efficiency as the frequency is increased, and degrade the performance of the thermionic valve as a converter of D.C. energy to R.F. energy. Even in the absence of other deleterious factors, they will eventually reduce the stage gain of an amplifier to unity, or stop the operation of a normal negative grid oscillator. Electron transit-time must therefore be regarded as a major limiting factor in the design of V.H.F. valves.

An additional effect of excessive transit-time which is not so well known is the introduction of unwanted phase modulation in an amplitude-modulated transmitter, even when the carrier is crystal controlled. It arises from variations of effective phase shift in the modulation stage (or in linear amplifiers following it) between peaks and troughs of modulation, is most marked in the troughs, and increases rapidly in magnitude as 100 per cent. amplitude modulation is approached. This phase modulation gives rise to

† Executive Engineer, Radio Experimental and Development Branch, E.-in-C.'s Office.

[1] Bell, Gavin, James, and Warren, "Triodes for Very Short Waves—Oscillators," *J.I.E.E.*, Vol. 93, Part IIIA, No. 5, pp. 833-46.

additional side frequencies which may cause interference to other services and which can cause distortion of the wanted modulation when the receiver bandwidth is too narrow to accommodate them. The phenomenon is relatively unimportant in transmitters handling a single audio channel ; but it can be of importance in multi-channel systems where distortion limits are more stringent, and may be a limiting factor in V.H.F. single-sideband operation where filter pass-bands are closely fitted to the wanted frequency spectrum.

Valve Capacitances and Lead Inductances.

At low frequencies a valve may often be regarded as a small item added to, or tied across, an external tuned circuit ; but in V.H.F. amplifiers the unavoidable capacitances and inductances within the valve envelope may form major portions of the tuned circuits, thus introducing serious problems in the design of inter-stage couplings. In the limiting case the circuit tends to vanish inside the valve. The internal capacitances and self-inductances of a triode are illustrated in Fig. **1**, while Fig. **2** indicates the self-

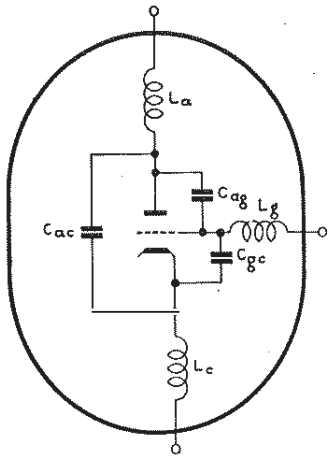


FIG. 1.—SELF-INDUCTANCES AND INTERNAL CAPACITANCES OF A TRIODE VALVE.

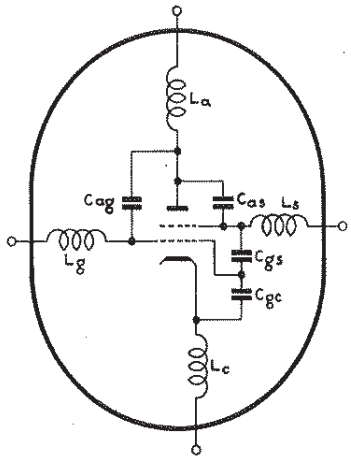


FIG. 2.—SELF-INDUCTANCES AND SOME OF THE MORE IMPORTANT CAPACITANCES OF A TETRODE VALVE.

inductances and some of the more important capacitances of a tetrode valve. Mutual inductances between leads have also to be considered in a full analysis of the operation of many V.H.F. valves.

Low input and output capacitances in a valve are of importance not only in ensuring reasonable circuit size at very high frequencies, but also on account of their influence on the maximum stage gain and bandwidth realisable, since to a first approximation the product of gain and bandwidth for any specified form of interstage coupling network is inversely proportional to the shunt capacitance. Because of transit-time limitations it is impossible to reduce capacitances in V.H.F. valves by increasing inter-electrode spacings, and capacitance between the active sections of adjacent electrodes can be reduced only by decreasing their areas. Stray capacitances between leads and supports make no useful contribution to the operation of the valve, and it is particularly important that they should be as small as possible. Since a V.H.F. valve often forms the main tuning capacitance, reasonably close tolerances on input and output capacitances are most desirable if interchangeability is to be ensured.

In addition to the effect of lead inductances on circuit size, individual leads may be of special importance in particular circuits. For example, in the case of an amplifier valve with the cathode as the " earthy " electrode, self-inductance in the cathode lead may seriously reduce the shunt input resistance of the valve. If the cathode lead inductance is L_c and the grid-cathode capacitance is C_{gc}, then the input resistance resulting from the inductance of the cathode lead is given by :—

$$R_i = \frac{1}{\omega^2 g_m L_c C_{gc}} \quad \ldots\ldots\ldots (2)$$

where ω is the angular frequency, and g_m is the mutual conductance of the valve. For fixed frequency operation L_c can be eliminated by series tuning, and in many cases a correct choice of the cathode resistor by-pass capacitance is all that is required. Lead inductance can be minimised by using short connections of large surface area, and on account of the large circulating currents which may occur, especially in narrow-band transmitters, low surface resistivity is desirable.

When the external circuit becomes very small it is often convenient to use a short section of transmission line instead of a coil as the external inductance. A coaxial line less than $\frac{1}{4}$-wavelength long and short-circuited at the far end has an inductive input reactance and can be used as a self-shielding inductance of relatively low loss. A line of low characteristic impedance will give the maximum external circuit size, but high characteristic impedance and short length are preferable in wide-band V.H.F. amplifiers.

Unwanted Feedback.

The phenomenon of unwanted feedback of energy from anode to grid in normal radio-frequency amplifiers is well known and requires little comment. In early triode amplifiers it was countered by " neutralisation," and it led to the development of tetrode and pentode valves. By the use of a close-mesh screen electrode, reasonably wide spacings, and adequate external shielding, the anode-to-grid capacitance can be reduced sufficiently to allow very satisfactory results at broadcast frequencies. At very high frequencies, however, wide spacings are barred by transit-time troubles, a close-mesh screen leads to high screen current, and the inductance of the screen lead prevents proper earthing of the screen electrode so that the efficiency of the screening is reduced.

On account of the difficulty of producing satisfactory V.H.F. transmitting tetrodes or pentodes, neutralised triodes have been extensively used in power amplifiers. Satisfactory neutralisation is not, however, easy to achieve. Although the well-known capacitive bridge arrangement shown in Fig. **3** is satisfactory at, say, 5 Mc/s, a more complex arrangement, such as that shown in Fig. **4**, is generally necessary at, say, 200

Mc/s. Unless the inductances of the grid and cathode leads are small, they will have to be series-tuned by capacitances C_g and C_c, in addition to adjustment of

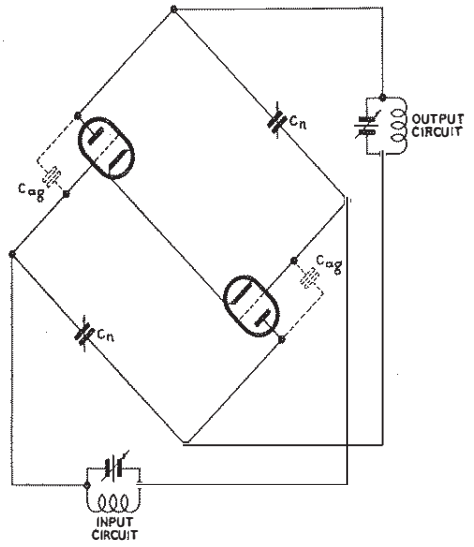


FIG. 3.—TYPICAL NEUTRALISING ARRANGEMENT FOR PUSH-PULL TRIODE AMPLIFIER OPERATING IN BAND 6 OR 7.

the normal bridge balancing capacitances C_n. As these adjustments are to some extent inter-dependent, correct neutralisation can be quite difficult.

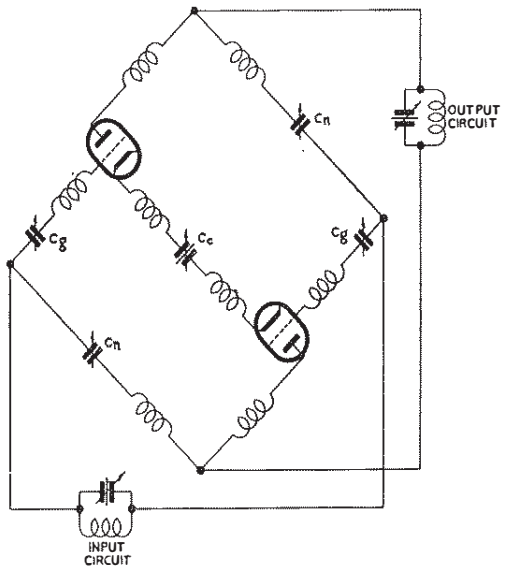
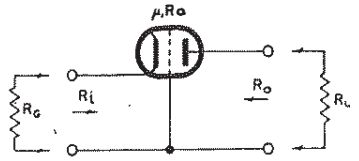


FIG. 4.—TYPICAL NEUTRALISING ARRANGEMENT FOR A PUSH-PULL TRIODE AMPLIFIER OPERATING NEAR TOP OF BAND 8.

The grounded-grid amplifier, shown in schematic form in Fig. 5, is a convenient alternative which also employs triode valves. In this case the cathode is used as the high potential input electrode, the anode is the high potential output electrode, and the grid which is common to the input and output circuits forms an electrostatic shield between them. The arrangement has the advantage of simplicity, and avoids the need for neutralising capacitances. It is extensively used both for V.H.F. transmitters and as an input stage in V.H.F. receivers. In a grounded-grid amplifier the



$$\text{Input Resistance} = R_i = \frac{R_a + R_L}{\mu + 1}$$

$$\text{Output Resistance} = R_o = R_a + (\mu + 1)\,R_g$$

$$\text{Power Gain} = \frac{R_L}{R_i} = (\mu + 1)\,\frac{R_L}{R_a + R_L}$$

FIG. 5.—SCHEMATIC DIAGRAM OF GROUNDED-GRID AMPLIFIER, AND BASIC LOW FREQUENCY FORMULÆ.

anode current returns to the cathode through an external circuit which includes the impedance between the grid and cathode. The feedback introduced in this way has the effect of making the output resistance of a grounded-grid stage high, and the input resistance very low. In multi-stage grounded-grid amplifiers, an impedance transformation is therefore necessary at each inter-stage coupling network. The input resistance of a grounded-grid stage depends on its anode load, and the output resistance depends on the impedance between cathode and ground. Thus input and output circuits are not independent and tuning a multi-stage amplifier of this type is a relatively difficult process. In valves for grounded-grid operation, low grid lead inductance is generally very desirable, although for some fixed frequency applications a suitable value of grid inductance can be used to minimise unwanted feedback through the anode-to-cathode capacitance.

Noise.

At low frequencies, thermal agitation voltages due to random motion of electrons in external circuits generally set a limit to the smallest voltage which can usefully be amplified. The magnitude of the thermal agitation voltage across a resistance of R ohms, measured in an effective frequency bandwidth of B c/s, is given by :—

$$\text{R.M.S. voltage} = \sqrt{4kT\,BR} \quad \ldots\ldots\ldots\ldots (3)$$

where k is Boltzmann's constant (approximately $1{\cdot}37 \times 10^{-23}$) and T is the absolute temperature (273 + °C). For example, the thermal agitation voltage across a resistance of 100,000 ohms at room temperature is approximately 2·2 microvolts R.M.S. for a bandwidth of 3,000 c/s.

At very high frequencies, however, circuit impedances and the thermal agitation voltages associated with them are less than at lower frequencies, and noise due to the random nature of the electron stream within the valves is generally predominant. As has been indicated in Part 3, valve noise is dependent on the construction and operating characteristics of the valve concerned, and is appreciably greater for multi-electrode than for triode valves. High slope at a low current is always desirable when low levels of valve noise are desired, and minimum possible

screen current is of great importance in the design of low-noise pentode or tetrode valves.

Although cathode lead inductance has such a marked effect on input admittance of a valve at very high frequencies, its effect on noise performance is relatively small, since degenerative effects on noise and signal are approximately equal. Electron transit-time, on the other hand, has a major effect on the noise performance of a valve, the noise level increasing appreciably whenever the transit-time exceeds a small fraction of one cycle. Low transit-time is therefore essential in the design of low-noise V.H.F. valves.

The overall noise performance, or noise factor[2], of an amplifier is a function not only of the valves employed in its early stages, but also of the circuit arrangements with which they are associated. A triode used as a grounded-cathode amplifier generally gives a slightly lower noise factor than when used in a grounded-grid arrangement, but neutralising may be required. Considerable attention has recently been devoted to the design of input circuits giving the optimum noise factor for a given valve, and one of the most successful developments is the combination of a grounded-cathode triode feeding a grounded-grid triode as illustrated schematically in Fig. **6**, and

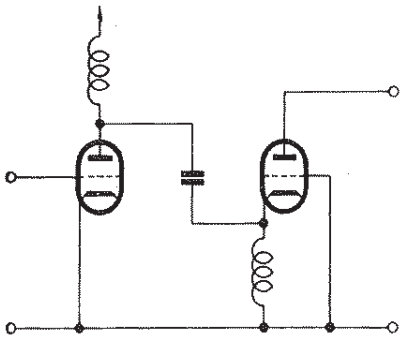


FIG. 6.—SCHEMATIC DIAGRAM OF A "CASCODE" AMPLIFIER.

generally known as a "cascode" amplifier[3]. This makes use of the low noise factor of a grounded-cathode arrangement of the first valve, and avoids instability by providing it with a very low impedance load—the input resistance of the grounded-grid stage.

Summary of Desirable Features in V.H.F. Valve Design.

Before discussing typical V.H.F. valve designs, it may be of value to summarise some of the more desirable features:

(1) Low transit-time; i.e., small inter-electrode spacings and large current densities.

(2) Low capacitances with close tolerances; i.e., small active electrodes, minimum stray capacitances in supporting structures, and precision methods of assembly.

(3) Electrode leads of low inductance and low surface resistivity.

(4) High slope.

(5) High reliability; i.e., long and uniform life.

(6) Ease of connection to suitable external circuits; i.e., valve and circuit should merge into one composite structure, but valve replacement should not be difficult.

(7) Good internal shielding.

(8) Efficient cooling of anode, grid, and screen in transmitting valves.

(9) Low fluctuation noise in small signal valves; i.e. high slope at a low cathode current, and in pentode or tetrode valves minimum possible screen current.

(10) High cathode emission, especially in transmitting valves; but low heater or filament consumption.

(11) Rugged mechanical design, and freedom from microphony.

(12) Ease of manufacture, and low cost.

Progress in Conventional Receiving Valves.

One of the first successful lines of progress in the development of V.H.F. receiving valves was the scaling down of the dimensions of normal valves and a rearrangement of the connections to produce the well-known "acorn" range of valves. These valves use small electrodes at close spacings, and minimise unwanted capacitance due to supports by relatively wide spacing of the connections to the electrodes, and elimination of the normal valve-base. The leads are short and of low inductance, and the input resistance of acorn valves in the V.H.F. band is roughly ten times that of corresponding receiving valves of normal design; but the manufacturing difficulties are considerable.

The CV1136 (Mullard RL7) is an interesting example of an alternative approach to the problem of making a satisfactory V.H.F. amplifier valve. This valve has an electrode structure of normal size supported by very short leads from a glass base, and cathode lead inductance is reduced to the absolute minimum by using four pins of the 9-pin base for the cathode connection. Separate cathode pins can be used for individual by-pass returns.

As examples of modern British practice in mass-produced V.H.F. receiving valves we may take the CV138 and CV139 which were developed under the auspices of the Services Coordination Valve Development Committee. These are miniature valves on B7G bases, and are illustrated in Fig. **7**. Their low frequency characteristics are summarised in Table I. The CV138 is a general purpose high-slope pentode valve with a limiting frequency for satisfactory operation determined partly by transit-time and partly by the self-inductance of the single cathode lead. For fixed frequency applications above about 150 Mc/s it is advantageous to series-tune the cathode lead (e.g., by suitable choice of the cathode resistor by-pass capacitance), and a useful stage gain can then be obtained up to frequencies of the order of 200 Mc/s. The CV139 is a high-slope triode for use as a low-noise R.F. stage in V.H.F. receivers: it was designed

[2] Moxon, "The Noise Characteristics of Radar Receivers," *J.I.E.E.*, Vol. 93, Part IIIA, No. 6, pp. 1130-42.

[3] Wallman, Macree, and Gadsden, "A Low-Noise Amplifier," *Proc.I.R.E.*, 1948, pp. 700-8.

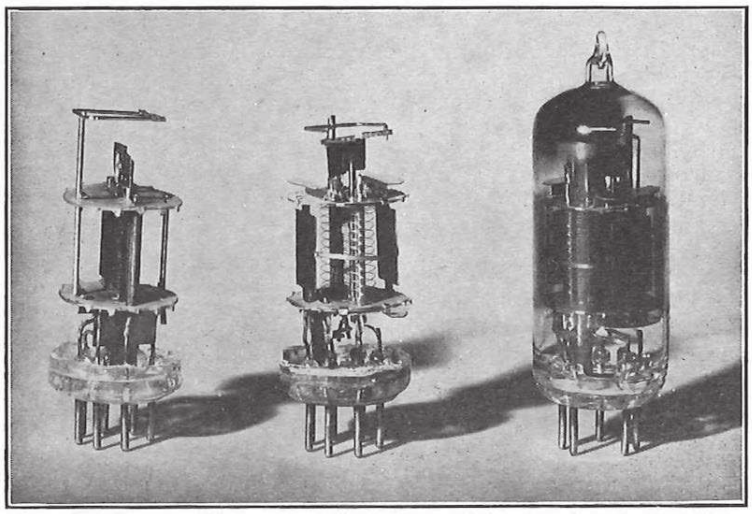


FIG. 7.—MODERN MINIATURE RECEIVING VALVES. (LEFT) INTERNAL STRUCTURE OF CV139 TRIODE; (CENTRE) INTERNAL STRUCTURE OF CV138 PENTODE; (RIGHT) CV138.

primarily for grounded-grid operation, and twin grid leads are provided.

TABLE I

Characteristics of V.H.F. Receiving Valves

			CV138	CV139
Heater voltage		(volts)	6·3	6·3
Heater current		(amps)	0·3	0·3
Max. anode dissipation		(watts)	2·5	2·5
Max. screen dissipation		(watts)	0·8	—
Input capacitance, cold		(μμF)	7·6	5·1
Output capacitance		(μμF)	3·2	3·6
Output-to-input electrode capacitance		(μμF)	0·008	0·1
Normal operating conditions	Va	(volts)	250	250
	Vs	(volts)	250	—
	Vg	(volts)	−2	−1·5
	Ia	(mA)	10	10
	Is	(mA)	2·6	—
	gm	(mA/V)	7·5	9
Input resistance at 45 Mc/s		(ohms)	8,200	—

Post-war progress in the field of mains-operated V.H.F. receiving valves has included two major developments. The first of these is the introduction of high-slope pentodes in the "sub-miniature" range of valves designed for direct soldering into circuits. Since the very small electrode assemblies of these valves, the short internal leads, and the absence of a valveholder result in low capacitances, low transit-time, and low lead inductances, they have a very good performance as Band 8 amplifier valves. The second line of progress has been the development, to at least a pre-production stage, of miniature triode valves having much lower transit-time, lower noise and lower capacitances than the CV139, and capable of operating efficiently in the lower part of Band 9. Such valves are of great value in low-level wide-band amplifiers, and a promising line of further development might be the combination of two of these triodes in one envelope for operation as a "cascode" amplifier stage.

The development of battery valves for operation above 30 Mc/s lags considerably behind that of mains operated valves. A range of battery acorn valves was introduced in America some years ago, but manufacture is difficult and the cost is high. For operation up to about 100 Mc/s, British 1·4 volt battery valves on B7G bases are now readily available; but there is a marked need for low consumption B7G-based valves which will give satisfactory stage gain and low noise at frequencies well above 100 Mc/s, without sacrifice of other essential features such as uniformity and long life. Sub-miniature battery valves of the soldered-in type have recently been introduced, and although not designed specifically for operation at very high frequencies, their very small electrodes, close spacings and relatively short internal leads result in quite good performance over a considerable part of Band 8.

Progress in Conventional Transmitting Valves.

When the process of improving V.H.F. performance by scaling down dimensions is applied to transmitting valves, one of the first problems encountered is that of cooling the small electrodes involved. The choice of anode material for radiation-cooled V.H.F. valves is a matter of compromise between such requirements as high melting point, high thermal emissivity, ease of fabrication, good mechanical strength, freedom from distortion or evaporation at high temperatures, ease of degassing during processing, and low cost. The materials most commonly used are molybdenum, tantalum, and carbon, and various surface treatments may be applied to improve performance. Carbon is an excellent radiator of heat, but is difficult to degas in thick sections and mechanically weak when thin. Tantalum is capable of operating at higher temperatures than carbon or molybdenum, and though an expensive material, it has the additional advantages of easy degassing during manufacture and a certain amount of "getter" action during normal operation. The grid in a V.H.F. power amplifier valve normally has to dissipate appreciable power, and as the grid structure must operate in close proximity to an incandescent cathode and a hot anode, efficient grid cooling is often a major problem.

Some widely used V.H.F. triodes of pre-war design are illustrated in Fig. 8. Recent progress in radiation-cooled valves of this class has been confined primarily to the reduction of lead inductance, especially of filament leads, and a number of improved designs have been produced.

The V.H.F. performance of conventional tetrode and pentode transmitting valves is limited to a large extent by long cathode and screen leads. Some progress can be made by shortening or duplicating these leads, but an alternative approach to the problem is the assembly of two tetrodes in the same envelope. These valves are designed for push-pull operation, and because of the proximity of the two electrode structures, low inductance interconnections can be provided between the two cathodes and the two screens. In some cases an internal by-pass

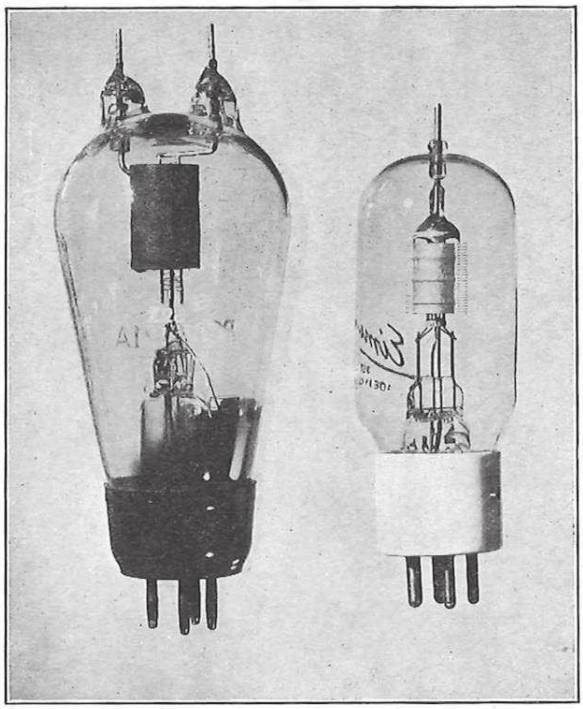


FIG. 8.—PRE-WAR RADIATION-COOLED TRANSMITTING TRIODES. (LEFT) CV1288; (RIGHT) 35T.

capacitor between cathodes and screens is also built into the valve envelope. The CV2666 and CV222 valves illustrated in Fig. **9** are examples of the twin-tetrode technique. The former has two 20-watt tetrodes in a double-ended envelope, and with suitable external circuits can be used up to a little over 200 Mc/s. The CV222 is a single-ended valve on a B9G base, and each anode is rated at 7·5 watts.

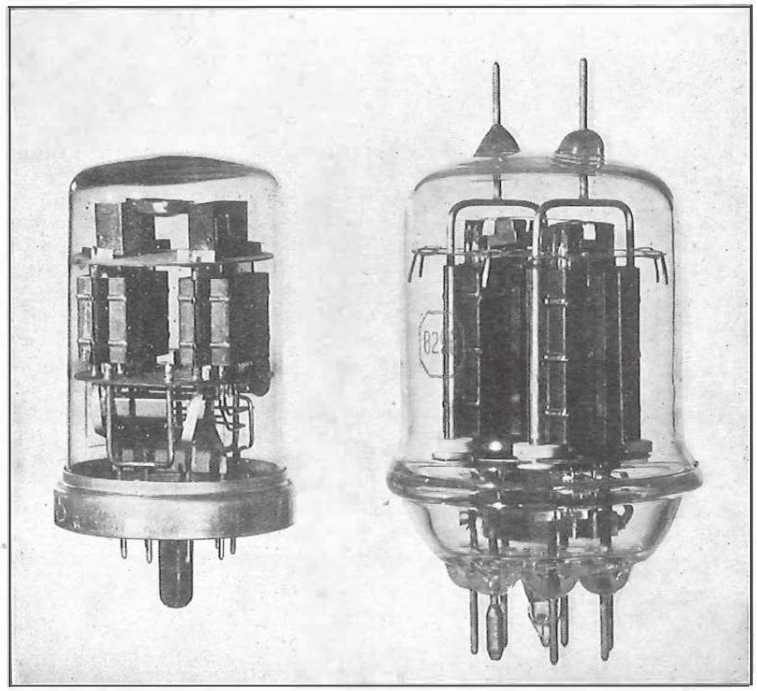


FIG. 9.—TWIN TETRODES. (LEFT) CV222; (RIGHT) CV2066 (829B).

Towards the upper limits of power and frequency, recent British development work on negative grid valves suitable for large-scale production has been concentrated primarily on external-anode triodes for forced-air or conduction cooling, and progress in this field has been considerable—especially among valves intended for pulse operation. Space does not permit a consideration of the many intermediate phases in the development of glass-metal V.H.F. valves, and descriptions will therefore be restricted to some of the more advanced designs suitable for use in C.W. amplifiers.

Ring-Seal Valves.

The most outstanding progress of the last decade in V.H.F. valves has been the exploitation of metal-to-glass sealing technique to give electrode connections in the form of discs or tubes of extremely low inductance and resistance. This technique has been applied particularly to triode valves, and has resulted in a readily available range of valves designed to operate as an integral part of coaxial line circuits[1]. Some examples of ring-seal transmitting triodes are illustrated in Fig. **10***, and their main electrical characteristics are outlined in Table II.

TABLE II

Characteristics of Ring-Seal Valves

		CV288	CV257	CV397	CV273
Heater voltage	(volts)	13·5	6·3	6·3	6·3
Heater current	(amps)	2·9	4	1·0	0·4
Max. anode voltage	(volts)	1,000	600	400	350
Max. anode dissipation	(watts)	250	75	20	10
Amplification factor*		40	22	35	30
Mutual conductance*	(mA/V)	30	20	12	6
* at anode voltage	(volts)	1,000	500	250	250
and anode current	(mA)	250	100	40	20
Anode-grid capacitance	($\mu\mu$F)	16·5	6·5	2·0	1·1
Grid-cathode capacitance	($\mu\mu$F)	22	13·5	4·5	2·3
Anode-cathode capacitance	($\mu\mu$F)	0·4	0·3	0·04	0·02

The CV273 and CV397 are intended for conduction plus radiation cooling, while the CV257 and CV288 use forced-air-cooled anodes. All have indirectly heated oxide-coated cathodes, close-mesh grids of very fine wire, and extremely small inter-electrode clearances. The CV288 has its active electrodes in the form of short cylinders, but the three other valves employ planar electrodes. These triodes can be used as grounded-grid amplifiers up to frequencies ranging from approximately 1,000 Mc/s for the CV288 to approximately 3,000 Mc/s for the CV273.

Although progress has not been so rapid in the large-scale commercial development of pentode or tetrode valves using ring-seal technique, various pre-production types have been produced. This technique allows the realisation of a very low screen lead inductance, and the screen assembly forms a continuation of the external

* The valves shown in Fig. **10** were developed in the Research Laboratories of the General Electric Co. Ltd., Wembley, England.

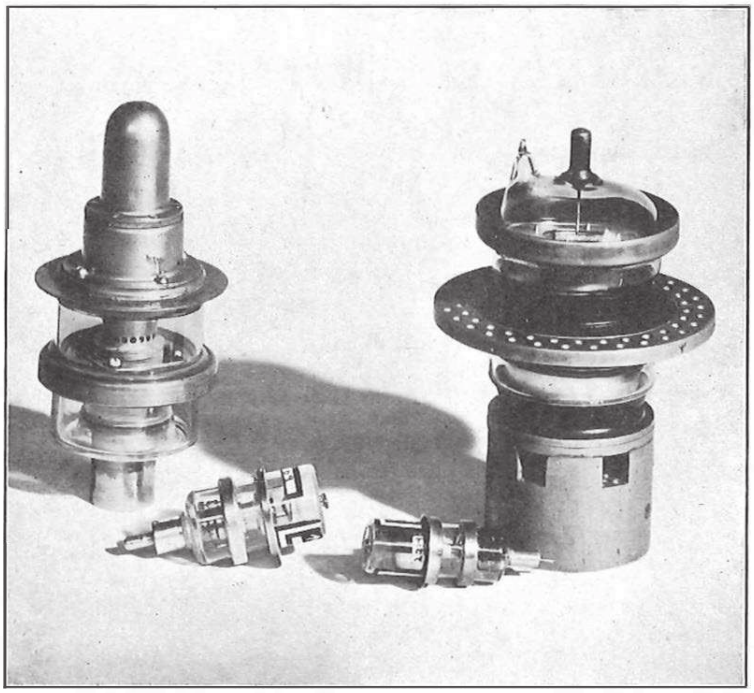


FIG. 10.—MODERN RING-SEAL TRIODES. (LEFT TO RIGHT) CV257, CV397, CV273, CV288.

shielding between output and input circuits. Further work seems to be desirable on ring-seal tetrodes or pentodes with built-in by-pass capacitors of negligible inductance between screen and cathode —possibly using a ring of high dielectric constant ceramic. Such valves would have important applications in multi-stage wide-band V.H.F. amplifiers, and the better isolation of input and output circuits of each stage would make alignment considerably simpler than in multi-stage grounded-grid amplifiers.

Conclusions.

The design requirements of valves for Bands 8 and 9 are fairly well established, and their further development is largely a matter of ingenuity on the part of the designer plus steady improvements in manufacturing technique.

Progress in recent years has been rapid, though perhaps somewhat uneven. In the receiving valve field, miniature triode and pentode valves are readily available in mains-operated types having a useful gain up to at least 200 Mc/s; but further progress is desirable in the development of small pentode valves for still higher frequencies. Economical battery valves which will operate efficiently at frequencies well above 100 Mc/s are also required. In the transmitting valve field, ring-seal triodes for grounded-grid operation have outstripped other types, but the development of comparable tetrode or pentode valves will be of great value.

Book Review

"Crystals and X-Rays." Dr. K. Lonsdale, F.R.S. G. Bell & Sons, Ltd. 199 pp. 138 ill. 21s.

Dr. Kathleen Lonsdale needs no introduction to physicists throughout the world. Engineers may be less well acquainted with personalities in X-ray crystallography, a science in which British physicists have played an outstanding role. Sir William Bragg and his son, Sir Lawrence, respectively past and present Cavendish Professors of Physics at Cambridge, have each done pioneer work in the subject. Dr. Lonsdale was fortunate in working as a student under Sir William Bragg, to whom she readily acknowledges indebtedness and gratitude. One may say that she has also acquired some of Bragg's power of lucid expression, a necessary quality of the complete scientist.

The book is based on a course of public lectures delivered in 1946, and the author states as her object the stimulation of interest among those who do not, but might well, use X-ray crystallography in their own work and the instruction of those others who do use it without fully understanding the power of the tool they employ. As a result, the book is a broad survey of present-day knowledge and techniques and there can be no doubt that few concerned with the subject will fail to profit by reading it. With her object in mind, however, Dr. Lonsdale has been compelled to take short cuts in order to cover the ground so that a layman may be excused if he does not grasp at first reading, for example, the Fourier synthesis, the reciprocal lattice and the space groups.

From the point of view of our membership, parts of the book will be found both easy to follow and instructive, and can be recommended without reservation. In particular, the first two chapters giving an historical introduction to the subject and a most useful and practical discussion on the generation and properties of X-rays are noteworthy and it is here where the lucidity already referred to is most evident. The last two chapters also, on extra structural studies and the importance of the study of crystals, will give the layman more than a glimpse of the power of X-ray methods in determining not only atomic structure, but how the data have added to chemical, electronic and metallurgical knowledge and are now making advances in biology.

The book is singularly free from errors, only the definition of the Angstrom unit on page 3 and printing T^3 as T_3 on page 150 being noticed. It is abundantly illustrated with diagrams and plates which include some beautiful examples of diffraction and absorption photographs. Dr. Lonsdale has given a comprehensive list of text books for more detailed and incisive study, although a few words outlining the scope and special features of each book would have helped the serious student. A welcome feature, now becoming more general, is the printing in heavy type of the main pages of reference to subjects in the index.

As an introduction, parts of the book will be difficult to follow, but to a student of the subject it is unique in the breadth, conciseness and authority of its survey.

J. D. H.

A Polarised Relay of Improved Performance

H. A. TURNER, B.Sc.(Eng.), A.M.I.E.E., and B. SCOTT, M.B.E., M.B.A., B.Sc.(Eng.), A.C.G.I., A.M.I.E.E.†

U.D.C. 621.318.522

A polarised relay in which the magnetic circuit and contact system differ from those of previous relays has been standardised for Post Office use. Tests have shown that the relay offers improved performance over existing relays as regards sensitivity and contact pressure while low transit time, symmetrical operation and absence of contact bounce result in very little distortion to signals. Ease of adjustment has not been sacrificed in obtaining these results.

Introduction.

AMONGST the apparatus requirements of modern telecommunications equipment is a relay which is more sensitive than the 3,000-type relay and which will also repeat impulses more accurately. The first important example of such a requirement was in System, Signalling D.C. No. 1 (the Long-Distance D.C. Impulsing scheme) where a polarised relay of S.T. & C. manufacture was used. This system is in service on a wide scale and reports indicate that a reliable service is being given.

With the development of the valveless System, Signalling D.C. No. 2 (the Single Commutation System) it became apparent that a relay of improved sensitivity would be advantageous. Attention was, therefore, directed to the Carpenter relay (type 4)[1] manufactured by the Telephone Manufacturing Co. which was of a size suitable for mounting on standard 3,000-type relay plates. Tests on the relay led to its adoption as a standard Post Office item, it being decided in the early stages to limit the physical requirement to a single changeover contact action.

The availability of the relay has simplified the work involved in designing both the Teleprinter Automatic Switching System and an improved 2 V.F. receiver, and as these two developments were being undertaken concurrently with the standardisation of the relay the requirements of both telephone and telegraph engineers were considered.

The relays have been coded in the Post Office range of relays as Relay, Polarised 2B, 3B, and 4B, depending upon mounting facilities. Individual designs of the relays will be differentiated by three-figure numbers following the initial code.

Figs. **1** and **2** are photographs of the relays with single changeover contacts, showing two different mounting arrangements.

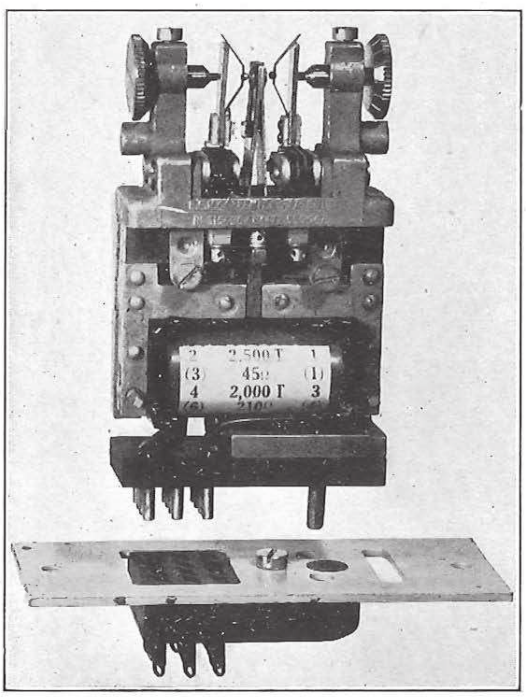


FIG. 1.—RELAY, POLARISED 2B WITH MAGNETIC SHIELD AND COVER REMOVED.

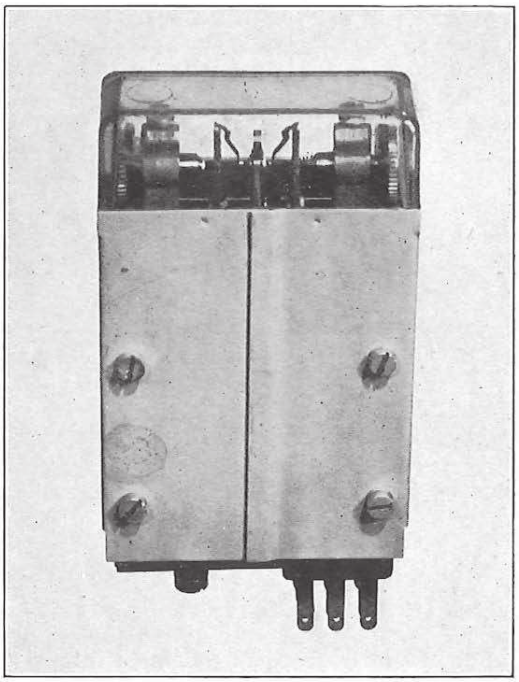


FIG. 2.—REAR VIEW OF RELAY, POLARISED 3B.

The Magnetic Circuit.

The components of the magnetic circuit can be seen in Fig. **1**, the circuit being represented schematically in Fig. **3**.

The controlling coil is wound on a former on a core completing a magnetic circuit between the two pole

†Mr. Turner, now Chief Engineer, Postal Dept., Sierra Leone, was formerly Executive Engineer, Telephone Development and Maintenance Branch. Mr. Scott is Engineer, Telephone Development and Maintenance Branch.

[1] R. E. H. Carpenter; Patents 315496, etc.

pieces. Placed symmetrically on the pole pieces are two magnets, polarity as indicated. An armature is suspended at a point between the permanent magnets and movement of the armature is limited by the fixed contacts.

In Fig. 3 (*a*) let Φ_{m1} and Φ_{m2} be the fluxes in

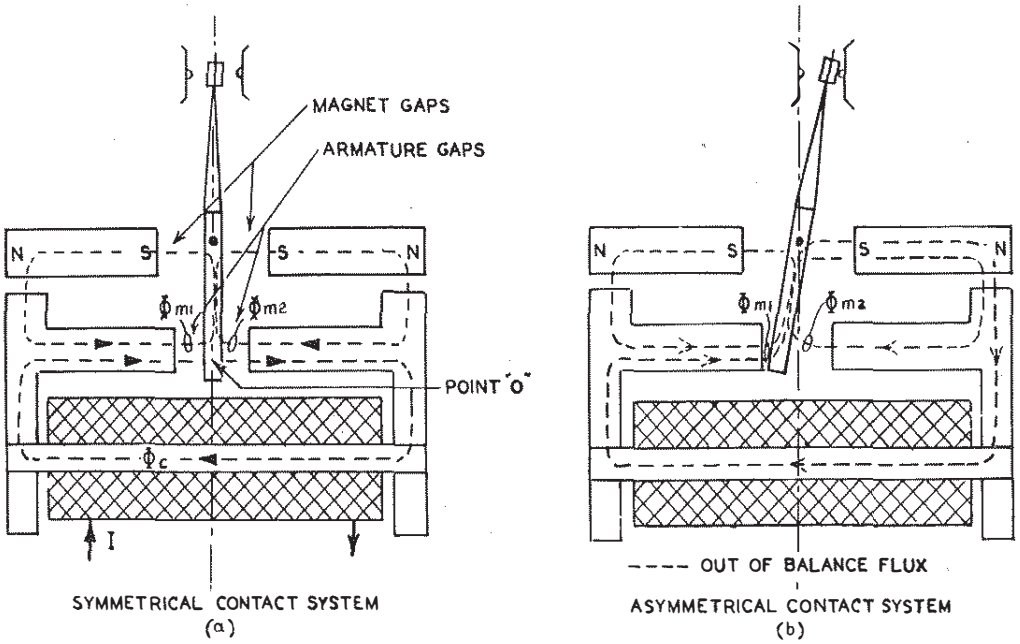


FIG. 3.—THE MAGNETIC CIRCUIT.

maxwells in the armature gaps due to the two magnets which are of equal pole strength and Φ_c that due to the current I in the coil. Then the general expression for the force, F, on the armature at the point O is :—

$$F = \frac{1}{8\pi A}\left\{(\Phi_{m1}+\Phi_c)^2-(\Phi_{m2}-\Phi_c)^2\right\} \text{ dynes} \ldots (1)$$

where A = effective cross-sectional area of armature gap in sq. cms.

Now, if the armature is held in the central position, as shown, the magnet gaps will be equal so that :—

$$\Phi_{m1} = \Phi_{m2} = \Phi_m \text{ (say)}$$

and it is possible to simplify expression (1) to :—

$$F = \frac{1}{2\pi A} \cdot \Phi_m \cdot \Phi_c \text{ dynes} \ldots (2)$$

Under free conditions the armature will move to the left and the force F is given by the general expression (1) and will increase with travel because Φ_{m1} increases and Φ_{m2} decreases as the air gaps change with the movement of the armature, the resultant out-of-balance flux passing through the core.

If there is no current in the coil, $\Phi_c = 0$, and in the central position $F = 0$, but this is an unstable condition and if the armature is deflected slightly off centre in either direction it will move over and take up a "side-stable" position where the force on the armature is given by :—

$$F = \frac{1}{8\pi A}(\Phi_{m1}^2 - \Phi_{m2}^2) \ldots (3)$$

The foregoing refers to the normal side-stable balanced relay and variations as follows may be considered.

If, as in practice, the pivot is a suspension spring this exerts a restoring torque ; if the spring is sufficiently thick it is possible for the armature to be held centrally in the no-current condition or, if a force has been applied to move the armature to one side, for it to be returned to the central position after the force has been removed. This condition gives a "centre-stable" relay, in which the armature contact touches one or other side contact only when there is a current in the coil. The only advantage of a centre-stable relay is that it can respond to three conditions instead of two, since the armature contact remains disconnected in the centre-stable position with no current and can switch to either side according to the direction of current flow. For all practical purposes, where a finite contact pressure is specified a centre-stable relay requires more ampere-turns from the controlling coil than a side-stable relay.

If one of the fixed contacts is offset from its symmetrical position, as in Fig. 3(*b*), the relay becomes one-side-stable. The operate ampere-turns figure is increased, but the armature will move on a disconnection of current instead of needing a reversal. The relay under this arrangement has a permanent bias.

A second winding permits an electrical bias to be applied as required, enabling the operate ampere-turns figure to be increased or decreased to detect different circuit conditions.

Three windings may be required in some cases in order to present balanced conditions to line together with bias facilities, making possible differentiation between balanced, unbalanced, and reversed line currents.

The relay can be used in the anode circuit of a

valve, a bias winding being used to neutralise the effect of the standing anode current and enable the relay to operate on the steepest part of the mutual characteristic.

Physical Description.

The major components of a Relay, Polarised 3B are shown in Fig. 4.

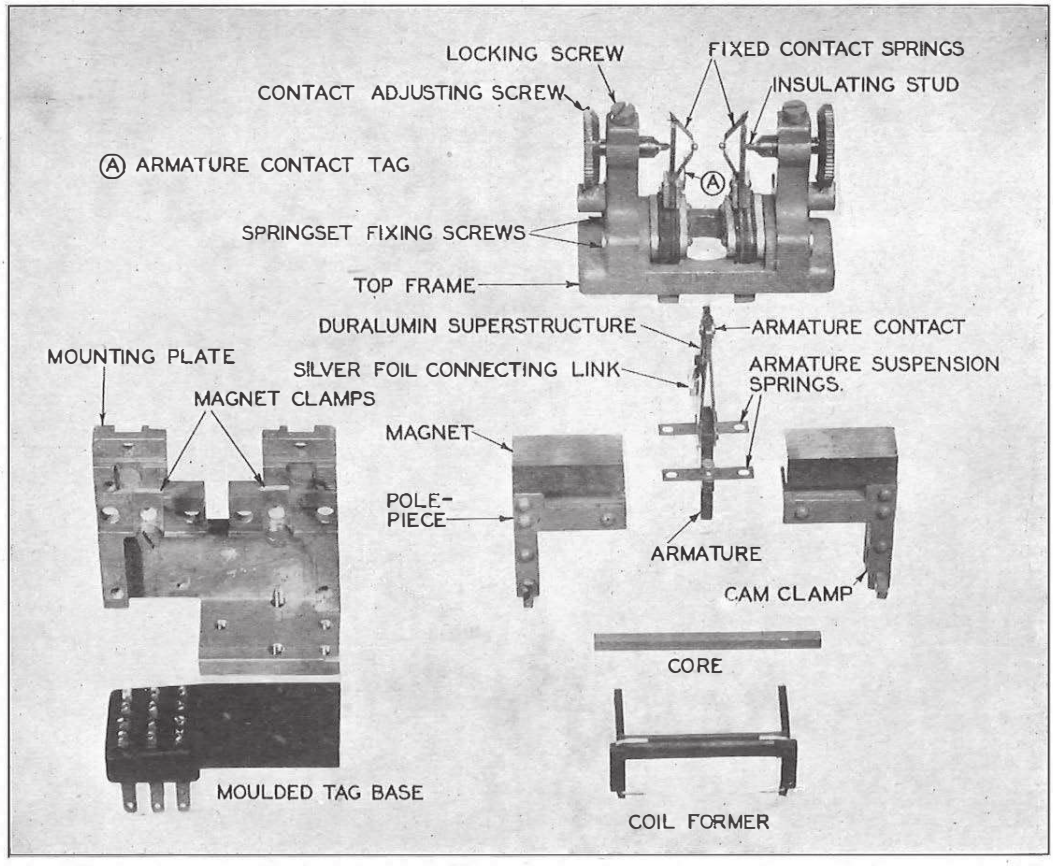


FIG. 4.—MAJOR COMPONENTS OF RELAY, POLARISED 3B.

Frame.—The mounting frame and top frame are die-cast in a non-ferrous alloy so that they will not affect the magnetic circuit whose elements they hold in place.

Magnets.—The magnets consist of bars of Alnico and are held in position with their North poles outwards by means of clamps and screws. These clamps hook under the top frame; therefore the top frame cannot be moved while the magnets are in position.

Pole pieces.—The pole pieces are laminated in order to keep eddy current losses to a minimum and are bolted to the mounting frame of the relay. The pole pieces for side-stable relays are made of radiometal which has a high permeability. If centre-stable or one-side-stable relays are introduced the pole pieces will be made of mumetal which has a lower magnetic hysteresis; this is of no benefit in a side-stable relay because the magnetic circuit, in providing side stability, leads to a mechanical equivalent of hysteresis which is very much larger than the magnetic hysteresis introduced by the pole pieces.

Core.—Owing to the shunt magnetic circuit the core carries none of the permanent magnet flux in the centre-stable position and only a small amount in the side-stable position; consequently it can be of very small cross-sectional area without causing the relay to saturate in the normal operating range. On the other hand the fact that it does saturate with excessive energisation protects the relay from magnetic and mechanical damage. The core is a solid bar made of mumetal to minimise the magnetic hysteresis due to the high energising flux density in the core which would otherwise appreciably affect the performance, even of a side-stable relay.

Coil Assembly.—The coils are wound on bakelite formers through which the core can be passed and clamped by the cams fitted in the pole pieces. The small size of core results in a lower resistance for coils than would otherwise be possible, the limits of coil capacity being as follows :—

Turns	Resistance (ohms)	Gauge (S.W.G.)
360	0·7	23
26,000	5,000	46

Up to four windings can be provided on a coil assembly; they are normally wound in enamelled copper wire with turns exact and resistance $\pm$ 20 per cent., sandwich winding being used for balanced windings. The inductance, L, of the windings, measured at 50 c/s, is given roughly by :—

$$L = 2{\cdot}5 \,.\, 10^{-7} \,.\, n^2 \text{ henries}$$

where n = number of turns.

The total heat dissipation from the coil assembly must be limited to a maximum of 2W; under these conditions the coil-to-coil and coil-to-relay insulation will withstand test voltages of 250V.

Contact Materials.—Copper-palladium, which has given an excellent performance in life tests, will be used as a standard contact material. Platinum contacts will also be available but the amount of metal required for the armature contact makes this expensive and the use of platinum will, therefore, be restricted to the more important types of telephone signalling apparatus.

Fixed-Contact System.—The fixed contacts are dome-shaped and mounted, as shown in Fig. **5**, on

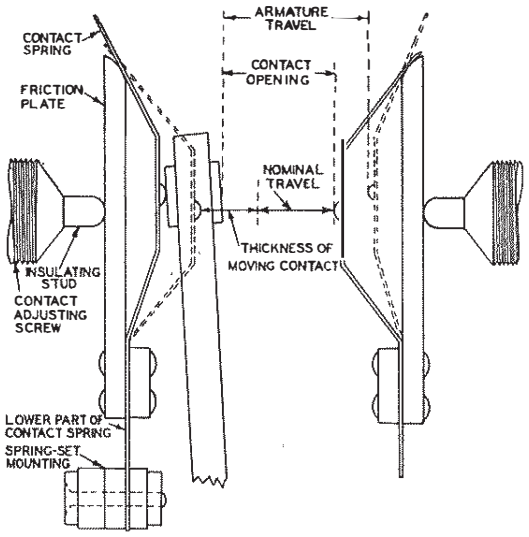


FIG. 5.—THE CONTACT ACTION.

beryllium-copper springs 10 mils. thick which are fixed at the lower ends and flex when contact is made, adequate damping being provided by the friction between the upper end of the spring and the plate against which it is tensioned. This form of contact mounting provides the bounce-free operation which is such an attractive point in the performance of the relay.

The contact spring extends beyond the point at which it is fixed to the plate down to the springset mounting, the lower part forming the flexible mounting that enables the plate and contact to be moved inwards by means of a contact adjusting screw with an insulated tip. This screw can be locked in position by a fibre pad inserted under a locking screw (Fig. **4**).

Armature Assembly.—The solid, radiometal armature is extended upwards to carry a moving contact between the fixed contacts, by means of a superstructure which is made of duralumin in order to keep the inertia to a minimum while providing mechanical stability.

In such a sensitive relay, firm mounting of the armature is essential as even a small relative movement between the armature and the magnetic circuit results in a change of sensitivity. Spring suspension strips, made of copper-beryllium, are used, thus avoiding the slackness that would result from worn pivots.

The armature assembly is mounted on these suspension springs so that it pivots about its centre of gravity to ensure that operation is unaffected by the position of the relay and to minimise the effect of vibration. The pivot line lies in a position between the magnet faces chosen so that redistribution of flux at the magnet gaps is kept to a minimum.

The armature contacts are of plate form to give satisfactory operation while the side contact springs flex and the contacts are sliding relative to one another. The contacts are riveted into an insulating bush in the duralumin superstructure and linked to a tag on the left-hand springset assembly by means of a loop of silver foil $\frac{1}{8}$ in. wide and 2 mils. thick which causes negligible bias.

Magnetic Shielding.—The magnetic circuit of the relay has a reasonable freedom from leakage, but in practice a magnetic shield is necessary to prevent crossfire effects to and from adjacent relays and to prevent the presence of adjacent iron masses affecting the performance of the relay.

For the 2B and 3B models the magnetic shield is of mild steel and not only serves as a guard to the magnetic system but also forms part of the cover which is completed by a transparent plastic moulding.

This arrangement allows the relay to be adjusted for sensitivity, neutrality, and timing, with the magnetic shield in position.

The earlier 4B model uses a mild steel cover as a magnetic screen but suffers from the disadvantage that the bias tends to change when the cover is replaced after adjustment for neutrality.

Relay Mounting.

The methods of mounting the relay are as follows :—

Relay, Polarised 2B.—This model plugs into a 12-way Jack No. 72 and was developed for use in telephone or telegraph equipment employing strip mounting plates. The Jack No. 72 is designed to fit the standard 3,000-type relay mounting and enables the relay to be withdrawn for adjustment or contact cleaning. The relay and jack can also be mounted on relay-set plates where it is difficult to obtain access to the relay for testing purposes, and this method is being adopted for the Teleprinter Automatic Switching System.

For most uses it is anticipated that the contact pins and the thick locating pin will be sufficient to hold the relay in position, but where abnormal vibration is experienced two locking screws can be passed from the back of the Jack No. 72 through the mounting plate and plug base and screwed into the mounting frame of the relay.

Relay, Polarised 3B.—This is a wired-in model which can be mounted in the standard 3,000-type relay

mounting and is intended for use in jack-in relay sets which can be taken to a bench for adjustment of the relay. The Mark 2 version of the tag assembly, which is shown in Figs. **2** and **4**, has been designed to be more rugged and to have better clearances than the earlier version.

Relay, Polarised 4B.—This model is used on certain telegraph switching equipment. The Jack No. **71** is of the Jones socket type and being rather larger than the Jack No. **72** requires a special drilling. The relay is retained in position by means of a clip which passes over the top of the cover.

General Factors Affecting Relay Performance.

Armature Travel.—The armature travel is adjusted by means of the side-contact adjusting screws, which are designed to give approximately 1 mil. travel of the screw for each division on the periphery of the screw head (16 divisions per revolution). Owing to the flexing of the contact springs the travel of the screws is not directly related to the armature travel (Fig. **5**). In practice, the travel is set by bunching the contacts with the armature in its neutral position and turning each screw back an equal number of divisions, the total of the two being known as the "nominal travel."

The actual armature travel is larger than the nominal travel owing to the flexing of the contact springs, actual figures being of the following order on a standard relay :—

	mils.	mils.	mils.
Nominal travel	2	3	5
Armature travel, unenergised	2½	3½	6
Armature travel, energised 15 amp.-turns	5½	7	9½

The contact opening measured at rest on a side-stable relay will lie between the nominal travel and the unenergised armature travel. For adjustment purposes reference to the "travel" will refer to the nominal travel unless otherwise stated.

The manner in which the travel influences the sensitivity, contact pressure, and transit time of the relay is described later.

Armature Suspension Spring.—With a spring thickness of less than 10 mils. (approx.) the armature is side-stable and remains held to the side on which it is placed, under the influence of the flux from the permanent magnets ; when the thickness is increased above 10 mils. (approx.) the spring exerts sufficient torque on the armature to retain it in a centre-stable position under unenergised conditions.

The relationship between suspension spring thickness and sensitivity, in terms of the ampere-turns required to operate the relay, is of the form shown by the solid lines in Fig. **6**, which show that maximum sensitivity is obtained with a 10 mils. spring. The contact pressure at the operate ampere-turns is, however, related to both the spring thickness and the travel as shown by the dotted lines. In practice it is necessary to ensure adequate contact pressure for reliable performance, but once the minimum pressure is specified the range of spring thickness and travel is limited to those parts of the curves above the pressure specified.

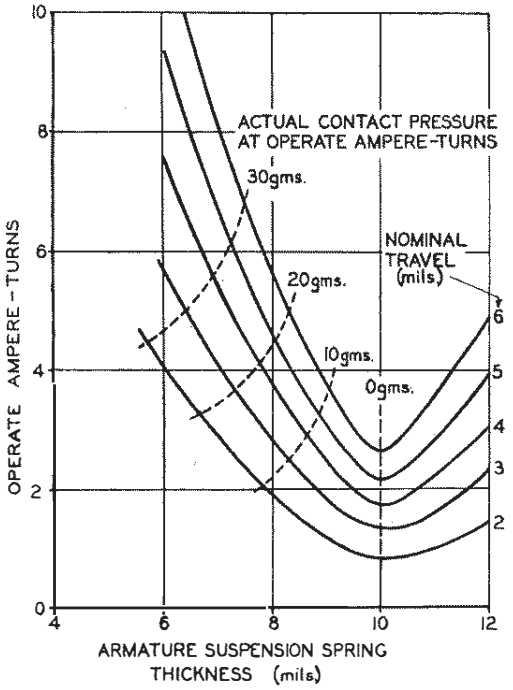


FIG. 6.—RELATION BETWEEN ARMATURE SUSPENSION SPRING THICKNESS AND SENSITIVITY ; SHOWING CONTACT PRESSURES AT OPERATE AMPERE-TURNS.

On Post Office standard models a spring thickness of 7·5 mils. has been adopted ; this ensures that the actual contact pressure does not fall below 12 gms. when the relay just operates at its maximum sensitivity, assuming a minimum nominal travel of 2 mils. With a 3 mil. nominal travel the minimum actual contact pressure rises to 18 gms.

Magnet and Armature Gaps.—The pole pieces are bolted to the frame with armature gaps of 8 mils. and located with great care to obtain mechanical symmetry. To enable the magnetic circuit to be balanced the magnets are sorted into pairs of equal strength before assembly, the magnet gaps being 30 mils. This sorting is necessary because the low incremental permeability of the magnet material makes it impracticable to adjust the permanent magnet fluxes by varying the air gaps.

If the relay is to remain unbiased over a wide range of energisation it is necessary for it to be mechanically and magnetically neutral. If mechanical bias is used to counteract magnetic bias due to the permanent magnets, neutrality can only occur at one value of energisation because the travel, and thus the effect of magnetic unbalance in the permanent magnet circuits, varies with energisation. Magnetic neutrality is arranged during assembly, as explained above, and mechanical neutrality by the use of equal contact spring pressures and by correct location of the pole pieces and fixed contacts relative to the armature.

If this balance is to remain satisfactory during service, neither the magnets nor the pole pieces should be loosened and moved. This makes the cleaning of

the magnet and armature gaps more difficult but since the magnetic shield on the 2B and 3B models normally remains fixed in place very little dust enters.

Tolerances.—Manufacturing limitations at present result in a variation in sensitivity between samples of ± 30 per cent. if they are all adjusted to the same travel; alternatively if a current test is used relays can be adjusted to a given sensitivity so long as a corresponding range is allowed in travel. The main causes of this variation in performance are firstly, the variation in stiffness of armature suspension springs and secondly, the fact that very small changes in the dimensions and materials of the magnetic circuit have appreciable effect on the performance. It is an important fact, however, that once assembled the relay remains stable.

On commencing production it was found possible to obtain an operate sensitivity of 4·7 ampere-turns on relays with a nominal travel of 3-5 mils., and since this was acceptable to the Post Office for many applications it has become a general specification standard.

Performance.

Some details of the performance of the single changeover contact side-stable model with 7·5-mils. armature mounting springs and contact spring pressures of 20 gms. are given below.

Sensitivity.—As already explained the sensitivity varies with armature mounting spring thickness but for a given spring thickness the sensitivity increases as the nominal travel is reduced. For Post Office use a minimum travel of 2 mils. has been adopted in order to provide reasonable contact clearance (which will be rather larger under dynamic conditions) and to avoid the necessity for frequent adjustment of travel to take up contact wear. A smaller travel also accentuates any mechanical instability that is present.

The relation between sensitivity and the nominal travel is shown in Fig. **7** which also shows the limits of sample-to-sample sensitivity which may be experienced.

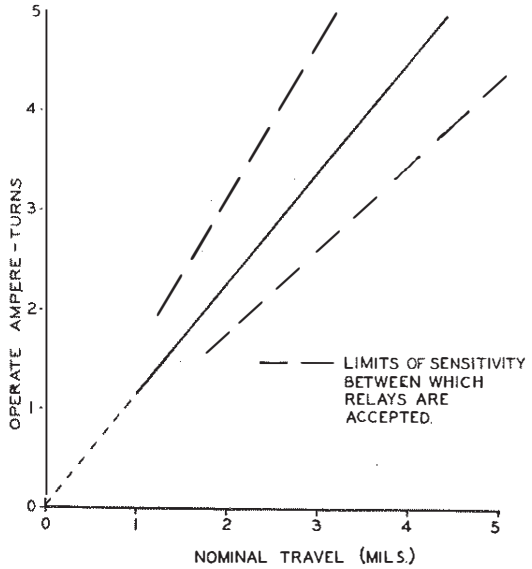


FIG. 7.—RELATION BETWEEN SENSITIVITY AND TRAVEL FOR 7·5 MILS. ARMATURE SUSPENSION SPRING.

Transit Time.—The transit time varies with the nominal travel, the energisation, and the constants of the operating circuit.

The relation between transit time (break-to-make) and nominal travel is of the form shown in Fig. **8**.

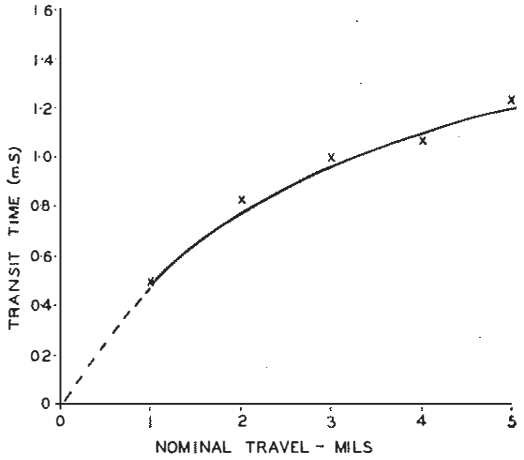


FIG. 8.—RELATION BETWEEN TRANSIT TIME AND TRAVEL WITH ENERGISATION OF 40 AMPERE-TURNS.

Specification of a minimum travel of 2 mils. sets the minimum time at about 0·8 mS. with energisation of the order of 40 ampere-turns with $n^2/R = 1{\cdot}1 \times 10^5$.

Considerable work remains to be done on the variation of transit time with energisation, but with an energisation of only 10 ampere-turns in the example above, the minimum transit time increases to 1·5 mS. A bias winding or short-circuited coil increases the transit time. As an example, a short-circuited 4,000-turn,750-ohm coil increased the transit time by 1·5 mS.

Contact Pressure.—For a side-stable relay the actual contact pressure is greater than the pressure necessary to separate the contacts as normally measured by a Post Office tension gauge. This is a result of the side contact following the armature contact for some distance, so that the force exerted by the armature at the point of separation is less than it was at the full deflection.

This is illustrated in Fig. **9** in which a represents half the nominal travel, and $(a + b)$ represents half the total armature travel, the contacts being closed during part b of the travel. The force, F, exerted at the contact by the armature increases with travel along the line ABC, but at B the contact spring begins to flex and exerts an opposite force, R, which increases along DC with the deflection of the spring; thus, summing these two, the force, T, measured hy a tension gauge follows the heavy line, starting from zero at E and increasing to a maximum at the point B where the contacts just break. Using 6-mils. contact springs and 7·7-mils. armature suspension springs on the single changeover model, the actual contact pressure is about 1·4 times the pressure measured by a tension gauge. The term "contact pressure" will refer in practice to the measured pressure, and the term "actual contact pressure" will be reserved for

the full pressure which is of interest in considering contact wear but is difficult to measure in practice.

For a centre-stable relay with 10-mils. armature suspension springs the actual contact pressure is normally within 10 per cent. of the measured contact pressure, while for 12-mils. suspension springs the

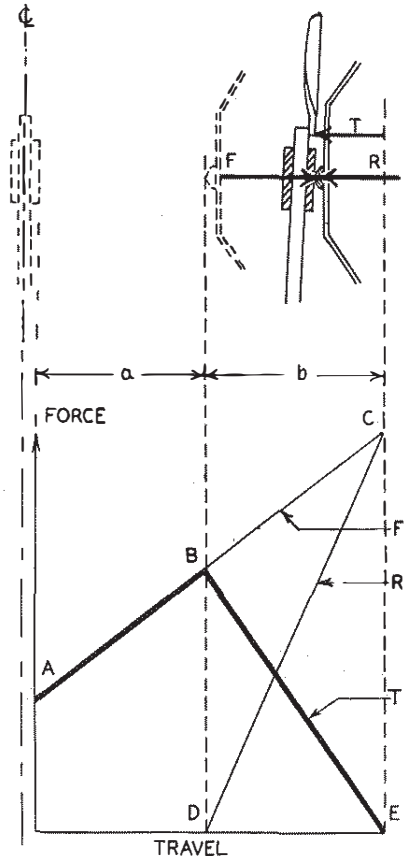


FIG. 9.—MEASUREMENT OF CONTACT PRESSURE WITH A TENSION GAUGE.

actual contact pressure is about 0·8 times the measured contact pressure.

For a given armature suspension spring thickness and contact spring thickness the contact pressure varies with both nominal travel and energisation.

The contact pressure increases linearly with nominal travel from zero at zero travel to 9·5 gms. (actual) at 5 mils. travel. With energisation up to 20 ampere-turns the contact pressure also increases on a linear basis (Fig. 10) but at this point saturation

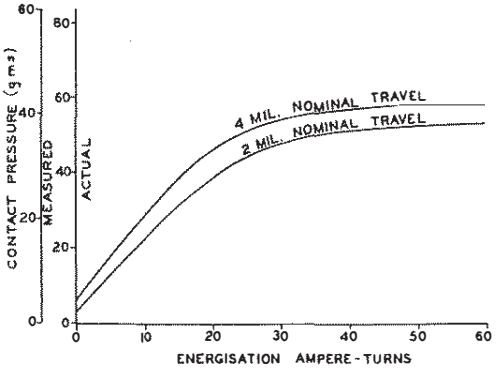


FIG. 10.—RELATION BETWEEN CONTACT PRESSURE AND ENERGISATION.

commences and becomes complete with an energisation of 60 ampere-turns.

Adjustment.

Laboratory work on the development of methods of adjustment indicates that the relay can be quickly and easily adjusted to meet a specified performance as to neutrality and sensitivity.

There are two approaches to the adjustment of the relay ; the first is suitable for applications in which the sensitivity is not critical because the circuit conditions provide for an energisation of at least 11 ampere turns. The method consists of just bunching the contacts by screwing in the contact-adjusting screws with the armature in an approximately central position and setting the nominal travel by screwing back each adjusting screw by half the travel required ; the relay is then energised with about 8 ampere-turns (R.M.S.) from a source with a symmetrical waveform and the bias measured on a D.C. bridge. The bias is then reduced to zero by screwing both screws an equal distance to one side or the other, thus maintaining the same nominal travel. An electrical test is desirable to detect the exact bunching point so that the contact springs are not flexed since this would result in an error in setting the travel. The 50 c/s A.C. power supply is normally suitable for energisation since the even harmonics, which introduce errors, are of very small amplitude in most Post Office stations.

Following this neutralising operation a D.C. test is made in each direction to check that the relay passes its test current figures ; in order to obtain consistent results it is necessary first to apply the saturate current in the reverse direction and next to check that the non-operate and operate currents are met.

The second approach is used when it is necessary to adjust the relay to a sensitivity within much narrower limits than can be obtained by the first method owing to the sample-to-sample variation in performance (Fig. 7). In such cases the D.C. test is carried out first, readjust figures being specified for non-operate and operate currents for one coil, test figures for the remaining coils and a range allowed for the contact opening. Following the D.C. test the relay is neutralised by the A.C. method, the same travel being retained in order to avoid changing the sensitivity. Finally, the D.C. sensitivity is rechecked and the contact opening checked by means of a feeler gauge.

When a low transit time is required the normal procedure is to adjust the nominal travel to a specified figure designed to give a satisfactory performance, and to rely on the sensitivity tests to show up any deterioration in the performance of the relay that will increase the transit time. Alternatively the performance can be checked on a telegraph distortion measuring set or an impulse distortion tester.

There will be some applications, however, for which a manual method of adjustment will be sufficiently accurate. This method depends on the fact that with a very small nominal travel a slight mechanical bias makes the armature one-side stable. The armature is stroked from side to side by the finger while the contacts are moved inwards ; if the armature re-

mains side-stable on one contact the opposite one is moved back slightly and the process of closing the contacts continued until bunching occurs. The use of lamps in series with the fixed contacts facilitates the procedure and ensures greater accuracy in determining the point of bunching ; the travel is then set by withdrawing each contact-adjusting screw by half the nominal travel required.

Applications.

The main advantages offered over previous relays are, improved sensitivity and contact pressure, absence of contact bounce, and low transit time, while the 2B and 3B models are also sufficiently small to be mounted in standard 3,000-type relay drillings. The fact that the relay is stable and simple to adjust is also of considerable importance.

The applications of the relay are growing in number ; the low transit time and absence of contact bounce together with the symmetrical action mean that the relay introduces very little distortion. This factor has led to its adoption in the System, Signalling S.C.D.C. No. 2, where the sensitivity of the relay facilitates the design of a circuit without valves that will pass impulses for distances up to 100 miles of cable.

The good impulsing performance has also led to the adoption of the relay in the 2 V.F. receiver and other impulsing circuits. In the Teleprinter Automatic Switching Scheme absence of contact bounce also makes it practicable to use the changeover contact action for operating the selector magnets, while the sensitivity of the relay makes it possible to leave the relay connected to line to await the clearing signal, because the total leak can be made of the order of 10,000 ohms and introduces little distortion to through signals.

In the System, Signalling S.C.D.C. No. 2 the relay is also used to respond to balanced, unbalanced, and reversed line conditions, the only advantage over other polarised relays being the saving in space.

Two-Changeover-Contact Model.

This model of the relay (Fig. 11) is in an advanced stage of development and is expected to prove useful in circuits where one of the changeover actions is used to pass impulsing signals forward while the other changeover action can be used for local control.

In order to equalise the contact pressures without complicated adjustment of the fixed contacts, a pair of self-aligning contacts is mounted on each side of the armature, the plates on which each pair of side contacts is fixed being mounted between pivots about which they can swivel. The plates tend to retain the position in which they are left owing to the friction in the pivots, but there is nothing to prevent bunching if one plate is displaced manually ; however, this is rectified immediately the armature is moved to the other side and contact pressures become equalised after a few strokes. It is, however, necessary to consider the possibility of bunching as a fault con-

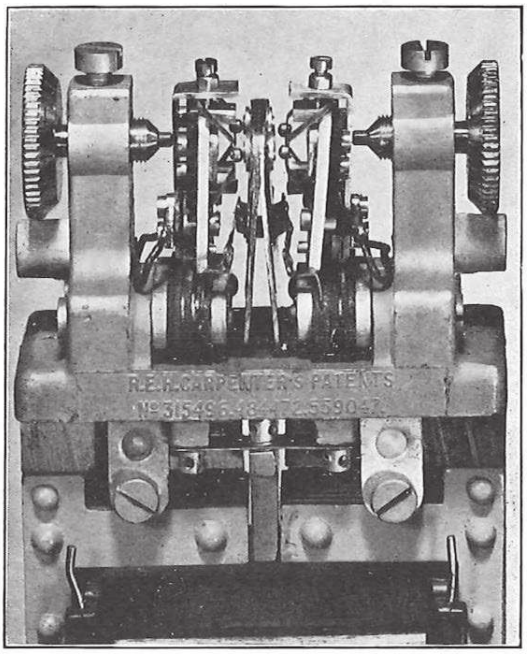


FIG. 11.—CONTACT SYSTEM ON TWO-CHANGEOVER-CONTACT RELAY.

dition should one pair of contacts become welded, but so far all efforts to cause bunching during tests of the relay have failed.

The relay is the same as the single-changeover model except for the armature superstructure and springset assemblies which carry the additional contacts ; the same mounting facilities will be available.

Acknowledgments.

The authors acknowledge the assistance given by the members of the Relay Group and the Circuit Laboratory of the Telephone Branch. Acknowledgment is also due to Mr. R. N. Hansford of the Research Branch for the basic work on variation of sensitivity with suspension spring thickness and on the measurement of contact pressure. In addition, thanks are due to the Telephone Manufacturing Co. for continued co-operation in the development of the standardised relay.

The London-Castleton Experimental Radio-Relay System

A. H. MUMFORD, O.B.E., B.Sc.(Eng.), M.I.E.E.
Capt. C. F. BOOTH, O.B.E., M.I.E.E.
R. W. WHITE, B.Sc., F.Inst.P., A.M.I.E.E.*

U.D.C. 621.397.743

The experimental wideband channel described in this article is a " single-frequency " relay system using frequency modulation with a maximum frequency deviation of ± 3 Mc/s, about a mean carrier frequency of 195 Mc/s. Attention is first drawn to the advantages and disadvantages of such a system as compared with the more usual arrangements involving frequency changing at each relay point ; an outline follows of the equipment fitted at intermediate and terminal stations, and the article concludes with some details of the overall performance obtained to date.

Introduction.

IN the article on Television Radio-Relay Links, published in the last issue of this Journal, brief mention was made of an experimental relay system set up by the Post Office Engineering Department. The transmitting terminal of this system is located at Rowley Lodge (near Barnet) and the receiving terminal is at the Post Office Radio Laboratory at Castleton (near Cardiff), with four intermediate repeater stations located at Green Hailey (near Princes Risborough), Widley (near Burford), Hook (near Swindon), and Wotton-under-Edge. The layout of the route is shown in Fig. 1.

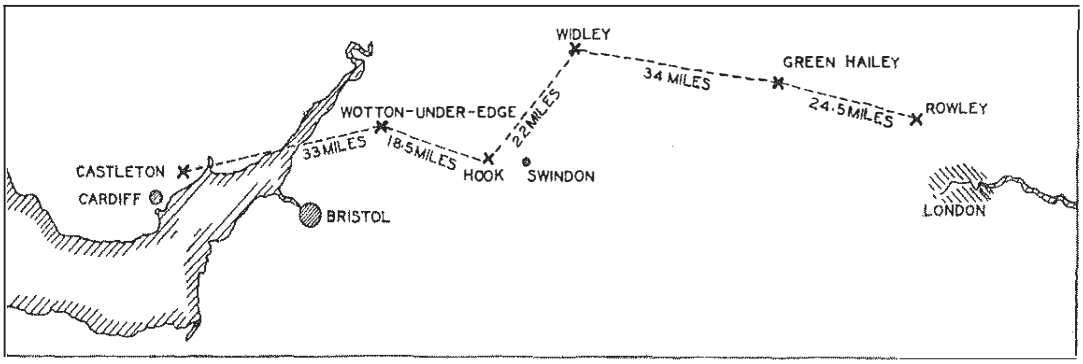


FIG. 1.—ROUTE OF THE LONDON-CASTLETON SYSTEM.

The link forms an experimental wide-band transmission channel and, although primarily designed to handle 405-line television signals, can also he used for preliminary investigation of radio-relay systems handling nnmbers of telephony channels. Since experience was required primarily on the radio system itself, and as it was not envisaged that it would be required to carry signals other than for experimental purposes, a control and supervisory system has not been provided.

It is normal practice in radio relaying to frequency-change at intermediate stations, but an unusual feature of this link is that the same frequency is transmitted throughout the chain, each repeater acting merely as a " straight " amplifier. Frequency modulation is used, with a total frequency excursion of 6 Mc/s from full white to the tip of the sync-pulse when transmitting television signals. The mean carrier frequency is 195 Mc/s, and the transmitted waveform is shown in Fig. 2.

Single-frequency operation of a radio-relay link has the merits of economy in frequency allocations, uniformity and comparative simplicity of equipment at intermediate stations, and the avoidance of spurious products resulting from frequency-changing processes. In such a system, however, unwanted signals differing only in time delay from the wanted signal, and thus capable of passing freely through the amplifying equipment, can be a major source of distortion. The avoidance of pick-up of signals arriving by different paths is the primary problem of a single-frequency system, and, in particular, very high attenuation (exceeding 120 db.) is necessary between the transmitting aerial and receiving aerial at an intermediate repeater station to avoid the production of " echo "

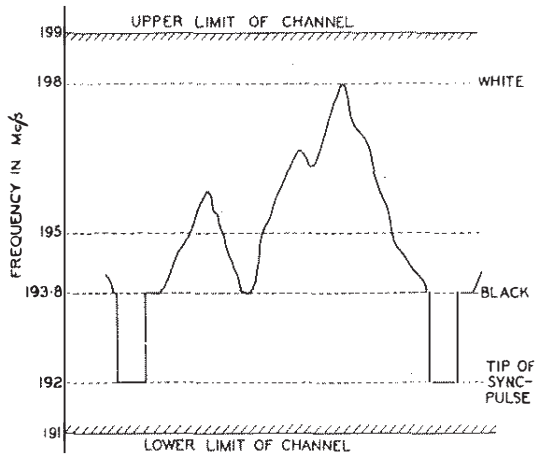


FIG. 2.—THE TRANSMITTED WAVE FORM.

* In order as listed above the authors are respectively, Staff Engineer, Radio Planning and Provision Branch; Staff Engineer, and Executive Engineer, Radio Experimental and Development Branch, E.-in-C.'s Office.

ignals by feedback from the transmitting aerial to the local receiving aerial. The high attenuation is obtained partly by the normal directivity characteristics of the aerials, but largely by spacing them up to 0·5 mile apart and locating them on opposite sides of hill-tops, as shown pictorially in Fig. 3. Two sites, a receiving and a transmitting site, are required at each intermediate repeater, the two being linked by buried coaxial cable for the transmission of the radio frequency signal. It will be appreciated that the selection of sites for a system of this type is very difficult. It is not just a question of obtaining a series of sites on the tops of hills, but of obtaining pairs of sites each below the brow of the hill, but on opposite sides, and each site being optically visible with respect to the next station. However, this difficulty must be balanced against the relative simplicity of the system. As was expected, considerable trouble was experienced not so much in finding suitable sites, but in getting permission to use them for the purpose in mind.

The five hops forming the complete link vary in length from 18·5 to 34 miles, the paths being optical in all cases. For the sake of the experiment, signals are received at Rowley direct from the B.B.C. television transmitter at Alexandra Palace (Fig. 4), and, after demodulation, the video signals are caused to frequency-modulate a transmitter. The modulated signals are amplified at each of the four intermediate repeaters. At each of these the incoming signal is received on a rhombic aerial, amplified and fed over a coaxial cable to the nearby transmitting site where it is again amplified to give an output of 10W which is fed to the transmitting rhombic. At Castleton the received signal is amplified and demodulated to give a video signal which is applied to a picture monitor.

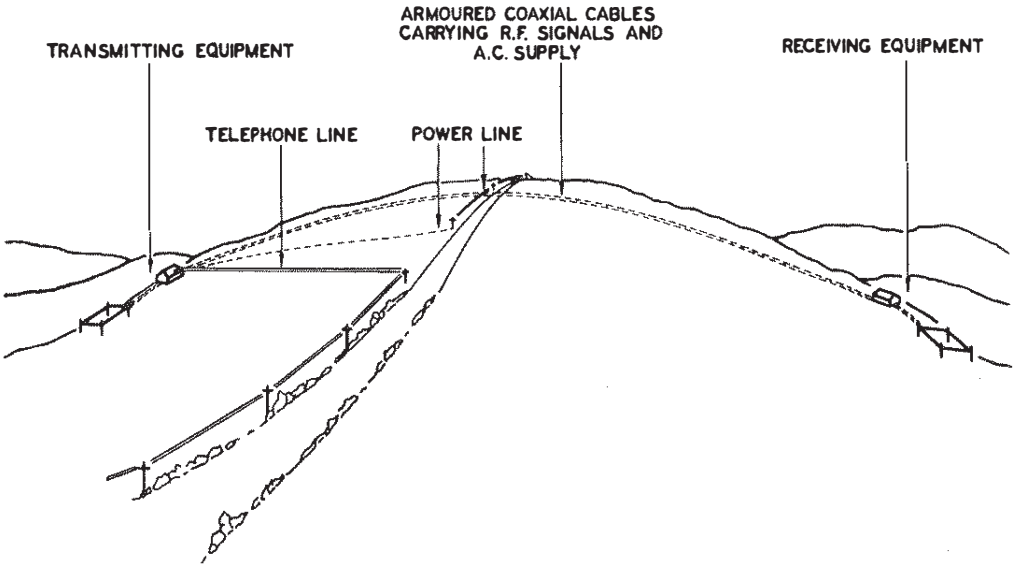


FIG. 3.—LAYOUT OF AN INTERMEDIATE RELAY STATION.

EQUIPMENT AT INTERMEDIATE STATIONS

The equipment at each intermediate station is divided between the receiving and transmitting sites as indicated in Fig. **5**. Internal equipment included in the main chain occupies three 6 ft. 6 in. racks of normal 19 in. Post Office pattern, two of these racks being classified as "Low-Level Amplifier Bays" and the third as a "High-Level Amplifier Bay." One low-level amplifier bay is used at the receiving site between the receiving aerial and the inter-site coaxial cable, and the other precedes the high-level amplifier bay at the transmitting site. Working and reserve equipment is provided at all intermediate stations, the reserve system at each repeater normally being arranged as a complete parallel chain. Rack-

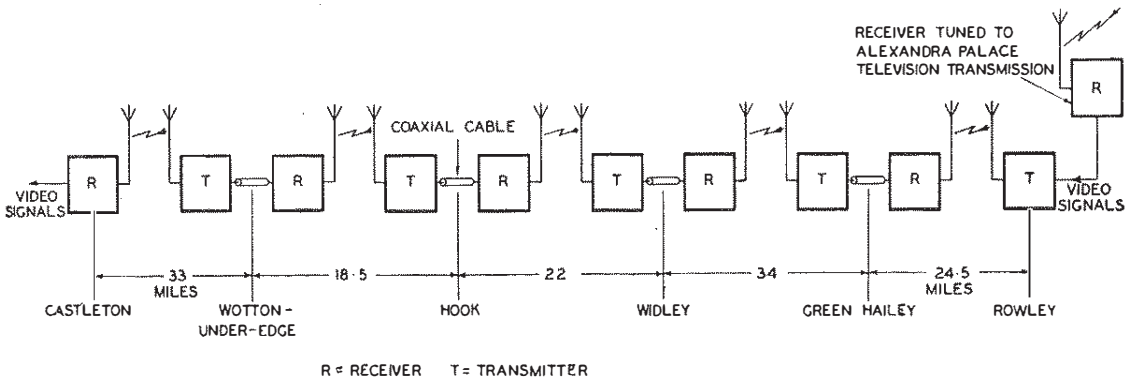


FIG. 4.—SCHEMATIC DIAGRAM OF THE SYSTEM.

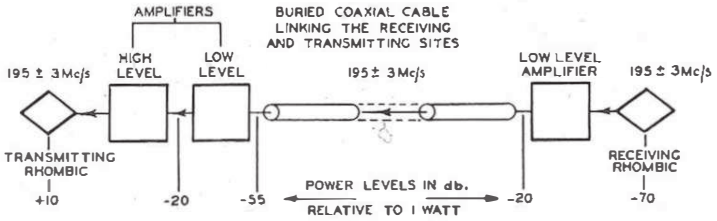


FIG. 5.—SCHEMATIC DIAGRAM OF INTERMEDIATE RELAY STATION.

mounted and portable test equipment is also provided.

Low-Level Amplifier Bays.

The low-level amplifier bays at receiving and transmitting sites differ slightly because of power feeding and control requirements, but the actual radio frequency amplifier units used in them are identical. Fan-assisted ventilation is employed on these bays to ensure low operating temperatures with a view to obtaining maximum possible valve and component life. In addition to accommodation for items essential to the main radio-frequency chain, and for power feeding, metering or control arrangements, space and power supplies are provided on each low-level amplifier bay to allow a demodulator of the type used at the receiving terminal to be jacked in for monitoring or test purposes.

The standard low-level radio frequency amplifier is a 14-valve unit on a vertical chassis and has been fitted with plug and jack connections to allow rapid replacement or interchange of units. The input stage uses a low-noise triode in a grounded-grid circuit, and this is followed by a main amplifier section comprising seven stages of CV138 pentodes with common-inductance-coupled double-tuned circuits as intervalve couplings. Stages 9 and 10 are limiters to remove amplitude variations, stage 11 is an output amplifier, stage 12 is a cathode-follower impedance-transforming output stage, and the remaining two valves are for monitoring and alarm purposes. Comprehensive metering facilities are provided. The amplifier is designed for 75 ohm input and output impedances, and provides a gain in the non-limiting condition of some 67 db. The input signal required for satisfactory limiting is of the order of —70 db. relative to 1W, and the output level under limiting conditions is — 20 db. relative to 1W, i.e. 10 mW. The amplifier is illustrated in Fig. 6.

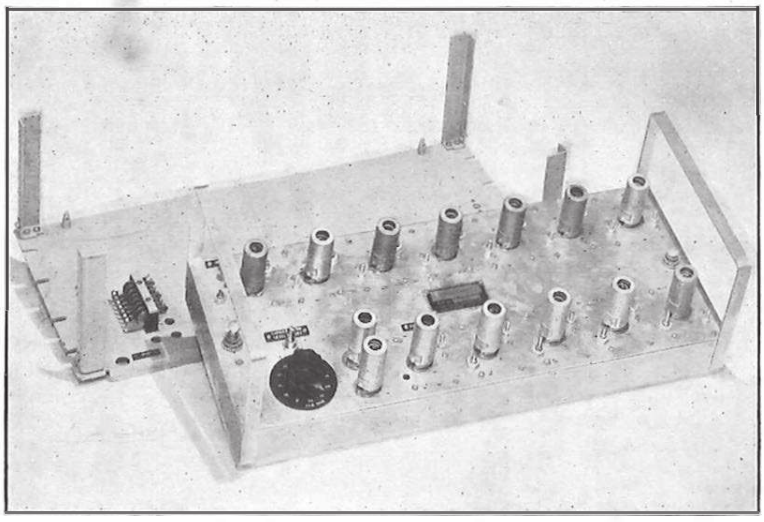


FIG. 6.—LOW-LEVEL AMPLIFIER UNIT.

High-Level Amplifier Bay.

The high-level amplifier bay is designed to operate between 75 ohm coaxial input and output cables, with a normal input signal level of 10 mW and an output level of 10W. It contains three amplifier units arranged in series, a five-stage input amplifier being followed by two single-stage amplifier units. Ring-seal triode valves in grounded-grid circuits are used throughout. Power units for these amplifiers and a blower for forced-air cooling are mounted on the same 6 ft. 6 in. rack as the amplifier units.

The five-stage amplifier uses CV273 triode valves operating at about 6W anode dissipation, and raises the power level from 10 mW to approximately 1W. The intervalve coupling networks take the form of top-inductance-coupled double-tuned circuits, arranged as impedance-transforming band-pass filters on account of the low input impedance which is a well-known characteristic of valves in grounded-grid circuits. The valves in this amplifier are arranged in a zig-zag manner through holes in a central screen, and lumped reactance circuits are used throughout. The general arrangement, with the stage screening covers removed, is shown in Fig. 7.

The single-stage amplifier unit uses a CV257 forced-air-cooled triode, operating with anode voltage of about 400 and an anode current of some 100 mA, i.e. appreciably under its maximum rating. The power output from the pair of single-stage units in series is at least 10W, for an input power level of 1W. Lumped reactances are used for most of the circuit elements, but an adjustable coaxial line of 4 in. diameter is employed as a variable inductor in the primary of the output coupling network. The forced-air supply to the anode of the CV257 is fed through the hollow tube inner conductor of this coaxial line circuit. A single-stage amplifier is illustrated in Fig. 8.

Cables and Aerials.

Working and reserve cables of an armoured air-spaced coaxial type are laid at a depth of 2 ft. between receiving and transmitting sites at each of the intermediate stations. Details of the cable are as follows :—

Inner conductor, copper . .
0·128 in. dia.

Outer conductor, lead . .
0·75 in. inside dia.

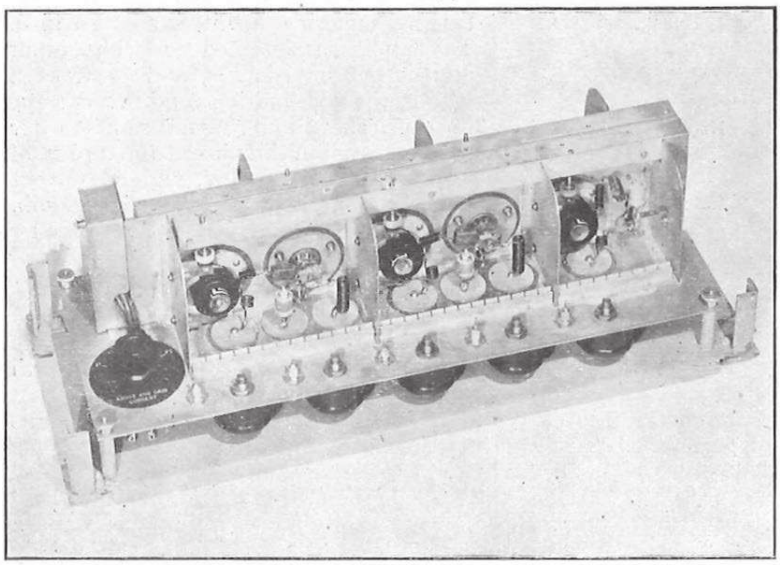


FIG. 7.—FIVE-STAGE GROUNDED-GRID TRIODE AMPLIFIER UNIT, WITH SCREENING COVERS REMOVED.

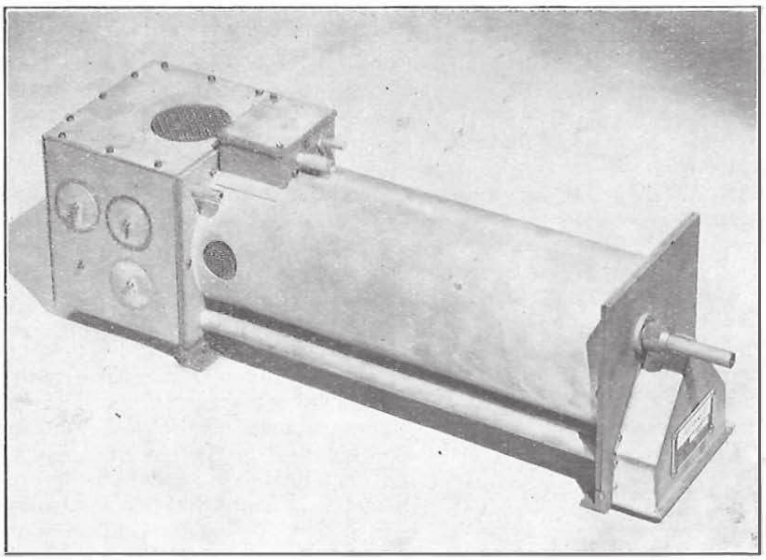


FIG. 8.—SINGLE-STAGE GROUNDED-GRID TRIODE AMPLIFIER UNIT.

Distrene spacers	.. ..	3 in. interval
Overall diameter including steel tape armouring	.. ..	1·39 in. dia.
Attenuation at 195 Mc/s	..	44 db. per mile
Characteristic impedance	..	102 ohms

The longest length of cable between sites is approximately two-thirds of a mile, giving an attenuation of just under 30 db. at a frequency of 195 Mc/s. To facilitate line-up of the system, however, the inter-site cable loss at all the intermediate stations is brought up to a standard value of 35 db. by external attenuators. Besides the radio frequency signals, each coaxial inter-site cable carries A.C. power from the transmitting to the associated receiving equipment, suitable filters being provided to separate the two sets of signals (195 ± 3 Mc/s and 50 c/s respectively), and the cable terminations include networks for transforming from 75 to 102 ohms. In addition to the coaxial cables, two twelve-core cables are laid between the two sites for control purposes.

Because of their mechanical and electrical simplicity and of their broadband frequency characteristics, rhombic aerials were chosen. Each rhombic (Fig. 9) has a length of some 100 ft., breadth of about 35 ft., and a height between 15 and 30 ft. depending on the slope of the ground in front of the aerial. The width of the major lobe in the horizontal plane is some 8° and in the vertical plane about 10°. The front-to-back ratio is about 25 db., and the forward gain is some 15 db. relative to that of a half-wave dipole.

Test Equipment.

Fairly comprehensive monitoring and test facilities are desirable on an experimental link such as this, and equipment provided at each intermediate station includes the following :—

(*a*) Demodulators (working and reserve) to allow extraction of the modulation from the signals passing through the repeater.

(*b*) An oscilloscope with a Y-amplifier having a satisfactory amplitude and phase response up to 5 Mc/s, for examination of demodulated video, pulse, or square waveforms.

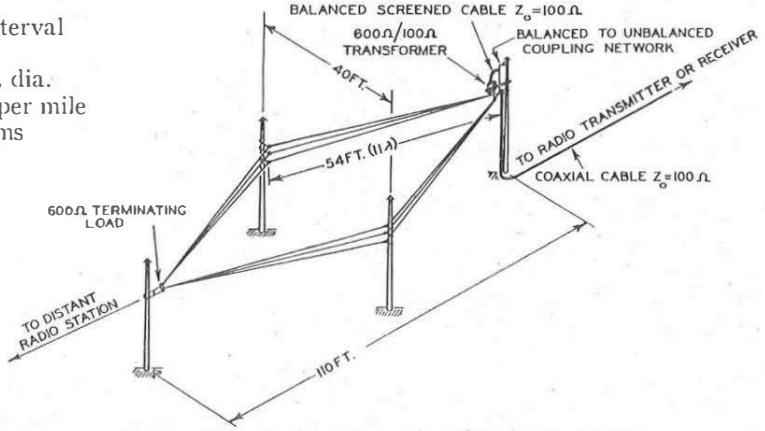


FIG. 9.—TYPICAL ARRANGEMENT OF RHOMBIC AERIAL.

(*c*) A simple narrow-band receiver covering some 180-210 Mc/s for examination of the radiated radio frequency spectrum, measurement of relative levels of carrier and side frequencies, and investigation of any spurious signals in or near the operating band.

(*d*) A scanning oscillator with crystal-controlled frequency "markers" to facilitate alignment of amplifiers on site, and to simplify any changes of bandwidth required.

(*e*) Reflection coefficient display and measuring equipment (associated with the scanning oscillator) which greatly facilitates aerial and feeder adjustments, and can be used to check input impedance of equipment over the band.

(*f*) A radio frequency level indicator, artificial loads, a valve tester, meters, and various minor items of test equipment.

The demodulator units are duplicates of those used at the terminal receiver. They are normally accommodated on the working and reserve low-level amplifier bays at the transmitting site, and arranged to monitor the outgoing signal from the station; but they can be jacked into the low-level bays at the receiving site if required, and used to check the signal being applied to the inter-site cable.

Items such as picture monitors and standard signal generators are not provided on a permanent basis at each repeater, but are taken to specific stations as and when required. A transmitter drive in transportable form is also available, and signals can be initiated at any intermediate station if required.

Equipment at Transmitting Terminal

The Rowley Lodge transmitter occupies two 6 ft. 6 in. racks, a "Transmitter Drive Bay" and a "High-Level Amplifier Bay" respectively, as shown in Fig. **10**. As the system is an experimental one, equipment design—especially for the terminal stations—is not static, and various forms of drive equipment have been and are being used. In general, however, the video signal incoming to the drive equipment is applied to some form of reactance valve, and is caused to frequency-modulate an oscillator running at a sub-multiple of the desired carrier output frequency. The oscillator output is then frequency-multiplied, and amplified if necessary, to provide the desired carrier frequency of 195 Mc/s ± 3 Mc/s at a standard power of 10 mW. The output signal from the transmitter drive bay passes through a high-level amplifier bay to raise the power level to 10W, and is than applied to a rhombic aerial. The high-level amplifier bay and aerial system are similar to those already described for use at intermediate stations.

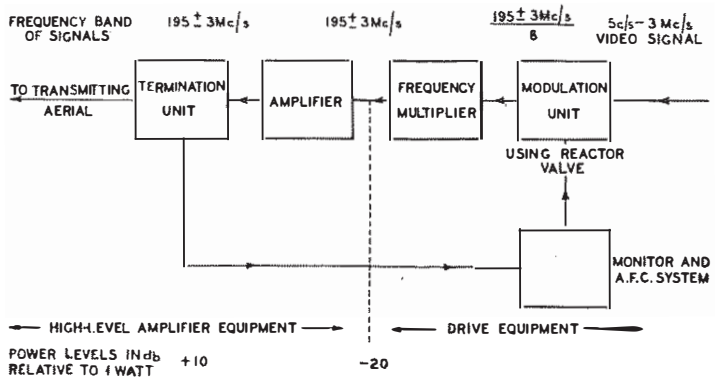


Fig. **10**.—Schematic Diagram of Terminal Transmitter.

Transmitter Drive.

In the modulator unit used for most of the earlier work on this link, the frequency-modulated oscillator operates at one-eighth of the final carrier frequency, as indicated in Fig. **10**. The oscillator is of the Hartley type, and two reactance valves are connected in parallel with its tuned circuit, one being used for video modulation and the other for automatic frequency control purposes. The frequency-multiplier stages are conventional, except for the use throughout of wide-band interstage coupling networks having a flat response over at least ± 3 Mc/s.

The automatic frequency control system is arranged to stabilise the frequency corresponding to the tip of the sync-pulse (Fig. **2**), and in the absence of an applied video signal the transmitter radiates 192 Mc/s, i.e. the D.C. component of a video signal is transmitted. A peak voltmeter across the video input to the modulator reactance valve is calibrated for use as a deviation meter, and an over-deviation alarm is associated with this. In addition, an independent over-deviation alarm based on instantaneous radiated frequency is included in the monitoring system.

Signal Sources and Test Equipment.

For experimental purposes various forms of modulating signal have to be applied to the link. Video signals are normally obtained by direct reception of Alexandra Palace transmission on a high-grade television receiver, but static test card patterns are also available, when required, from mobile monoscope equipment. Sine-wave signals from 10 c/s to 5 Mc/s are produced by a wide-range beat-frequency oscillator, and square wave sources cover 10 c/s to 200 kc/s. A pulse generator provides pulses adjustable in duration from over one line period down to one-third of a microsecond, with rise and decay times of just over 0·1 microsecond, and linear-phase-shift low-pass filters can be used to reduce the build-up times when required.

The radiated signal can be demodulated locally, and the monitoring equipment provided for checking it includes a picture monitor, and an oscilloscope having a Y-amplifier designed for operation up to 5 Mc/s.

Equipment at Receiving Terminal

The signal from the receiving aerial at Castleton is amplified by a standard low-level amplifier, as indicated in Fig. **11**, and is then applied to a demodulator unit which incorporates limiter stages, a dis-

criminator, and a video section. The receiver occupies a 6 ft. 6 in. rack, and is virtually a low-level amplifier bay of the type used at intermediate stations, but with

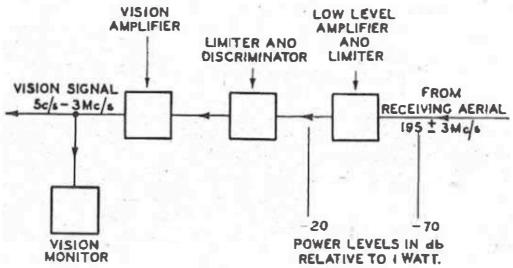


FIG. 11.—SCHEMATIC DIAGRAM OF TERMINAL RECEIVER.

the demodulator arranged as an integral part of it instead of just for monitoring purposes.

Demodulator.

The first valve in this unit is a CV139 triode operating as a grounded-grid amplifier, and the input impedance is adjusted to 75 ohms. The input stage is followed by a CV138 voltage amplifier, and this in turn feeds a primary limiter stage. A pair of secondary limiters which follow have their grids in parallel, but each anode feeds one half of a discriminator consisting of circuits resonant at approximately 189 and 201 Mc/s respectively. The outputs from the diodes in the two halves of the discriminator are amplified in separate single-stage video amplifiers before being combined and applied to a cathode-follower video output valve. Low internal impedance of the H.T. source is necessary for the video amplifier stages, and a series-valve H.T. stabilising system is included as an integral part of the demodulator unit.

The demodulator is designed to operate with a normal radio frequency input level of 10 mW, but it will operate satisfactorily on levels down to 5 mW. A frequency swing of $\pm$ 3 Mc/s in the applied signal provides a video output level of 1V peak-to-peak into a 75-ohm coaxial cable, and the demodulator is designed to handle satisfactorily modulation frequencies from 10 c/s to 5 Mc/s. In size and mechanical construction it closely resembles the low-level amplifier unit already illustrated in Fig. 6.

Monitoring and Test Equipment.

Testing facilities at the receiving terminal include almost all those available at intermediate repeaters, but a number of additional items of test equipment are also provided. In particular, a wide-band noise measuring amplifier and a range of low-pass filters are available for signal-to-noise ratio measurements, and video equalisers can be used to modify the overall frequency response of the link. Picture monitors are, of course, essential items, and two, of differing design, are normally associated with the receiver. In addition, the location of the receiving terminal makes available to it the normal measuring and test equipment resources of the Castleton Radio Laboratory. Before considering the results obtained to date it must be emphasised again that the link is only an experimental one and that it has not been engineered to the standard necessary for a system operating on a commercial basis.

PERFORMANCE

Pictures were first sent over the complete system on 24th March, 1949, and Fig. 12 shows a recent example photographed from one of the picture monitors at Castleton.

Since the tests commenced a considerable amount of experimental data on the radio-relaying of television signals has been accumulated. It was expected that the avoidance of pick-up of signals arriving by different paths would be the primary problem of a single-frequency link, and this has been confirmed by the results so far obtained.

Initial Results.

The first overall tests showed fairly noticeable distortion due to signals displaced in time from the wanted signal. These unwanted signals were of three distinct types—one advanced with respect to the main signal by approximately 1·5 microseconds, the second type delayed by from 5 to 7 microseconds, and the third delayed by a small fraction of a microsecond. The first was due to pick-up at Widley of signals direct from Rowley (i.e. by-passing Green Hailey), while the second type arose from pick-up on receiving aerials at repeater stations of signals from the local transmitting aerials. The third type of echo was due to irregularities in aerials and cables, mis-termination of aerials, feeders, and input cables to equipment, and probably to some extent to short period propagation echoes due to external reflections.

In the original relay link layout, successive hops were zig-zagged slightly to minimise direct pick-up of the "next-but-one" station; but loss of a site near White Horse Hill necessitated acceptance of a site at Widley such that the first two hops are almost in line, and also the introduction of an additional station at Hook. Aerial directivity is thus of little assistance

FIG. 12.—PICTURE RECEIVED ON MONITOR AT CASTLETON.

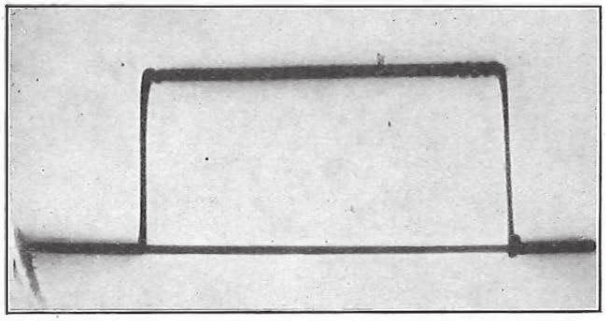
in minimising pick-up at Widley of direct signals from Rowley, and reduction of power at Rowley relative to the power radiated from Green Hailey has been necessary to reduce the advanced spurious signal to a reasonably satisfactory level. This can be done, of course, only at the cost of degraded signal-to-noise ratio on the Rowley-to-Green Hailey section, and increase in the relative level of the local " back-to-back " echo at Green Hailey.

Present Performance.

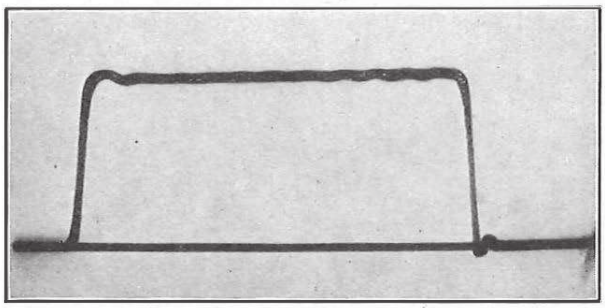
The overall characteristics required for transmission of 405-line video signals have been discussed in the article " Television Radio-Relay Links " already referred to, and the majority of the performance requirements specified therein are met by this link. Echo signals of the 5 to 7 microsecond group are a limiting factor, and have levels somewhat outside the specification figures. Considerable improvement has been effected, however, by increase of the front-to-back radiation ratios of aerials at repeater stations, and further work on aerial systems is in hand. There is a reasonable margin at present on signal-to-noise ratio, but some of this may have to be sacrificed in the reduction of echo signals. The pulse response of the link (Fig. **13**) shows that the build-up and overshoot requirements can be met.

Acknowledgments.

The authors desire to thank their many colleagues in the Radio Branches who have contributed so much to this experiment, and to express their appreciation of most helpful co-operation from the staffs of the Regions in which the stations are situated.



10 μS. Pulse, 50 kc/s P.R.F., 3 Mc/s Frequency Shift.



4 μS. Pulse, 120 kc/s P.R.F., 3 Mc/s Frequency Shift. Build-up and Decay (10 per cent. to 90 per cent.) better than 0·15 μS.

FIG. 13.—LONDON-TO-CASTLETON PULSE TESTS, 16TH AUGUST, 1949.

Book Review

" Terrestrial Radio Waves." H. Bremmer. Elsevier Publishing Co. Inc., New York. 344 pp., 91 ill. $6·75.

This book contains a rigorous mathematical treatment of the theory of the propagation of electromagnetic waves around a spherical earth with (*a*) a homogeneous atmosphere and (*b*) an atmosphere consisting of a troposphere and an ionosphere.

In part (*a*) the field intensity of the ground wave is first derived in the form of a series of zonal harmonics, which by Watson's transformation are later expressed as a series of residues in order to facilitate numerical computation. The conditions under which the various geometrical-optical methods may be used to calculate approximate values for the ground-wave intensity are then discussed. This part of the book concludes with a most useful chapter containing the results of many numerical calculations in the form of graphs of the field intensity plotted against distance for various frequencies, ground of various conductivities and dielectric constants and for a range of heights of the transmitter and receiver above the ground.

Part (*b*) deals first with the effect on the ground-wave intensity of refraction in an idealised, spherically symmetrical troposphere and later extends this to include the effects of super-refraction and duct formation in the troposphere. This part of the book also includes the theory of sky-wave propagation via the ionosphere, and the effect of the earth's magnetic field on waves reflected from the ionosphere.

Because of the rigorous mathematical treatment of the subject this book will be primarily of value to the wave-physicist ; nevertheless, since the theory is well illustrated by many numerical examples, it will also be of value to radio engineers concerned with the more practical problems of wave propagation. For the latter the main limitation of the book will probably be the absence of comparisons between the results of numerical calculations based on highly idealised conditions and the results of measurements of field intensity under conditions as they exist in practice. It is necessary, for example, to be very cautious in applying the results of calculations of field intensities on wavelengths shorter than about 1 metre, since the shadow effects of irregular terrain may lead to discrepancies of 10 or even 100 to 1 between the calculated and measured values of the field intensity. Other subjects which might be expected to come within the scope of a book on " Terrestrial Radio Waves " but which are not dealt with in the present volume include propagation over mixed terrain, e.g. land-sea boundaries, non-linear effects in the ionosphere, and the attenuation of centimetric waves by the atmospheric gases and by rain, hail and fog.

However, the treatment of wave propagation around a spherical earth under the highly idealised conditions assumed, is exceptionally thorough and rigorous, and the author is to be congratulated on the success he has achieved in extending and unifying existing theories on this subject. W.J.B.

OLIVER HEAVISIDE—An Appreciation

by

Sir George Lee, O.B.E., M.C., B.Sc., Past President I.E.E.

(ex-Engineer-in-Chief of the Post Office)

FROM time to time a genius springs up among us, and the world moves onward in some direction at a more rapid rate. Such a genius was Oliver Heaviside, and the particular direction in which the world moved was the improvement in telecommunications.

Heaviside, the centenary of whose birth was commemorated on 18 May, was a self-taught mathematical genius without any advanced mathematical education. He reached the age of 18 at a time when telegraphy was in its infancy, when duplex and quadruplex (which were subsequently invented by Heaviside) were not in existence. His uncle, on his mother's side, was the famous inventor and telegraph pioneer, Sir Charles Wheatstone, and it is probable that the influence of his uncle led Oliver into the telegraph field. The famous scientists, Faraday and Maxwell, had done their work on the fundamentals of electrical science and the telecommunications stage was thus well set for a man like Oliver Heaviside to enter, and his mathematics produced the fundamental sciences of telegraphy and telephony. Engineering does not advance by guesswork, it must have the science of a particular subject laid down mathematically, so that calculations can be made, and the effect of altering this or that component of the problem evaluated. The mathematics also points the way to further advances.

Heaviside commenced work as an operator with the Anglo-Danish Cable Co., and gained his practical experience in fault testing on this cable, and in experimenting with coils, condensers, batteries, telephones, etc.

From the age of 24, however, he worked entirely on mathematics. In telegraphy, Kelvin's KR law was the only transmission formula available, and in telephony there was none. Oliver set to work and put the transmission science on a very sound and practical basis. This is a very good example of the advantage of mathematics ; Heaviside's transmission formulæ showed at once that if you increase the inductance of a line you can reduce the attenuation, and in consequence telephone to a longer distance. He suggested the addition of coils at intervals in the telephone lines and also what we now know as continuous loading.

Professor Pupin, in America, experimented by adding inductances in the telephone line and the loading coil system was then born. The Post Office, in this country, commenced experimental work on loading coils in 1901, under Mr. Tremain, and the enormous network of loaded cables which we have at present was gradually built up. The valve amplifier came just before the 1914-18 war, and by inserting telephone repeaters in the lines at suitable intervals, the limit of talking distance was set by the time delay between question and answer when the time of travel of the speech along the line became too great.

Carrier working is now gradually superseding loading, though the latter is still necessary on shorter lines, where carrier working is not economical.

Heaviside's transmission formula also brought out another possibility, the distortionless circuit. This, however, though extremely interesting scientifically, has not been adopted practically, as it would be too expensive in repeaters. Also, carrier working is a better alternative from the standpoint of distortion.

Oliver Heaviside next turned his attention to wireless and he worked out many radiation problems. The most striking suggestion of his was that there was possibly a conducting layer in the upper atmosphere and that wireless waves might go round the world with their heads hitched on to the upper layer and their feet on to the ground or sea. This upper layer of ionised air was subsequently discovered by Appleton in 1925, at a height of 100 km. above the earth. Heaviside did not develop the idea any further and we do not know what led him to it. The value of this discovery is very great, as the seasonal changes in this and other higher layers, which were discovered by Appleton subsequently, have been mapped out, and the forecasting of the best short wave to use at a particular time in the future, for a specified route, is now carried out.

Heaviside lived as a recluse, in relative poverty. His mathematics were at first unacceptable to the orthodox mathematicians of this country, but by middle age he had been recognised, and before he died he was satisfied that his work was appreciated. We can now say that but for Heaviside, telecommunications would not have been developed to anything near their present extent at this present time. We are accustomed to thinking of telephones in terms of numbers of subscribers, but it must not be overlooked that without the possibility of talking to some distant subscribers, many people would not have a telephone at all.

Notes on the Centenary Meeting, 18 May, 1950

by

W. G. Radley, C.B.E., Ph.D., M.I.E.E.

(Deputy Engineer-in-Chief of the Post Office)

Oliver Heaviside was for a time a member of the Society of Telegraph Engineers, as the Institution of Electrical Engineers was called in its early days. It was, therefore, fitting that the Institution should hold a commemorative meeting on the centenary of his birth.

The centenary meeting was in two sessions. During the afternoon, the President of the Institution, Professor E. B. Moullin, was supported by Sir Robert Robinson, President of the Royal Society, and both paid tribute to Heaviside. Sir George Lee then described the kind of man Oliver Heaviside was; Sir George Lee's paper was based on personal accounts by Heaviside's friends and quotations from his own letters and books. We gained a picture of a man who lived alone and whom very few people knew. This man was outspoken in his criticisms and at loggerheads with many of his contemporaries, but had many likeable characteristics.

Following Sir George Lee, Sir Edward Appleton, Principal and Vice-Chancellor, University of Edinburgh, who was to broadcast on Oliver Heaviside later in the evening, spoke chiefly of the reflecting layers in the upper atmosphere which were suggested by Heaviside in an article written in 1902. The selection of this speaker was a happy one as he has contributed so much to our present knowledge of these layers which are of great importance to long-distance radio communication.

The present Engineer-in-Chief, Sir Archibald Gill, referred to Heaviside's contributions to long-distance line telephony and telegraphy and while regretting that his suggestions for the inductive loading of lines had not been more quickly taken up, emphasised the value loading had been to the development of long-distance telephony in the years immediately following the first World War.

Contributions followed from Dr. M. J. H. Ponte, President of the Société Française des Electriciens and Past-President of the Société des Radioélectriciens, who attended in person to represent French engineers, and from Dr. O. E. Buckley, President of the Bell Telephone Laboratories, U.S.A., who sent a recorded message.

Professor E. B. Moullin then read a message from Professor Harold Jeffreys, Plumian Professor of Astronomy and Experimental Philosophy, University of Cambridge, which had particular regard to the value of Heaviside's physical mathematics, and Sir Edmund Whittaker, Emeritus Professor of Mathematics, Edinburgh University, paid a nice tribute to Heaviside's work on behalf of mathematicians generally. The afternoon session closed with a racy account of some of the more personal aspects of Heaviside's life from Dr. G. F. C. Searle, who is one of the few living scientists who knew Heaviside personally.

The President opened the evening session by referring to the work which Mr. H. J. Josephs, a member of the Research Branch at Dollis Hill, had done in studying the Heaviside manuscripts in the possession of the Institution. These manuscripts include a large number of loose sheets of paper and notebooks, containing the mathematics upon which Heaviside worked during the latter years of his life. Mr. Josephs found that they contained many new and significant theorems which Heaviside had probably intended to publish in his Fourth Volume on "Electro-magnetic Theory." In a short talk which Mr. Josephs gave later, he pointed out that these theorems contained the formulation of a unified theory in which electro-magnetism is correlated with atomic structure, mass-properties and gravitation.

Professor Willis Jackson of the University of London, presented a paper reviewing various aspects of Heaviside's published work. He showed how Maxwell's Theory of Electro-magnetic Wave Propagation had been used in Heaviside's successful endeavour to develop a comprehensive theory of telegraph and telephone line transmission. He gave a selection of extracts from Heaviside's writings which illustrated the spontaneity of his style and his power of deductive reasoning. Professor Balth van der Pol, Director-General of the C.C.I.R., followed with an historical survey of Heaviside's achievements with his operational calculus.

The last paper of the evening was presented by the author of these notes, and consisted of a review of 50 years' development in telephone and telegraph transmission as related to the work of Heaviside. The audience was given a demonstration of the benefits to be obtained by loading cables, from speech reproduced over loaded and unloaded circuits in a Post Office cable. Reflection of pulses of high-frequency current travelling along coaxial cables by irregularities in the cable were shown on cathode ray oscilloscopes and Sir Edward Appleton's first experimental determination of the height of the Heaviside layer was shown in a miniature form within the Lecture Theatre.

The vote of thanks to all who had taken part was proposed to a well-filled Lecture Theatre, including many of Heaviside's relatives, by Sir Stanley Angwin, the last Engineer-in-Chief.

The papers presented, and the tributes paid to Heaviside at the meeting, will be published in a special issue of the proceedings of the Institution of Electrical Engineers. The paper by Mr. Josephs, presenting Heaviside's hitherto unpublished theorems, will constitute a permanent contribution to scientific and mathematical thought.

The Electrical Power System for Handling Cable in H.M.T.S. Monarch

A. J. THOMSON*

U.D.C. 621.315.284

Electrically-driven cable engines are employed in the *Monarch*, giving important advantages over steam-driven machinery. The author details the equipment concerned, explains its operation, and gives particulars of typical cable-laying operations carried out recently.

Introduction.

A SHORT description of the electrical power installation in H.M.T.S. *Monarch* was given in the general article on the vessel in the January, 1947, issue of the Journal. The system used is sufficiently novel, however, to justify a more detailed description, particularly, since it has now been in successful operation for three years. During this period *Monarch* has completed a sufficient number of repair and laying operations in the North and South Atlantic and the Mediterranean Seas, to compare performances with the more normal steam-driven cable machinery in use in other cable ships.

The essential requirements of cable-handling machinery at sea are flexibility, ability to stall on load for long periods and to pull away the cable slowly and steadily on the easing of the tension. Until the advent of the *Monarch*, the only drive considered suitable for these requirements was the triple-crank steam engine, which was eminently suitable for this class of work and appeared likely to hold this field indefinitely. The use of the constant current system, however, enables an electric motor to duplicate all the characteristics of steam engine performance and, in fact, to improve on them.

One disadvantage of the steam engine is the liability of the cylinders to become waterlogged when under prolonged stalled condition, with the consequent danger of cracked cylinder covers should the load take charge and rotate the engine. Under these same circumstances, the steam engine is sometimes difficult to start slowly and smoothly and, until cleared of condensate, is liable to jerk the cable. In addition, heat loss, by radiation from long steam pipe connections, can add considerably to the fuel bill. These disadvantages are eliminated in the motor drive whilst the desirable features of the steam engine are retained.

The Generator Room Equipment

The electrical generating plant is installed in a space 45 ft. × 35 ft. abaft the main engine room and comprises the following items: Two 200-kW geared steam turbine sets 8,000/1,200 r.p.m., each with self-contained condensing plant. Each turbine drives two 100-kW, 220-V D.C. generators in tandem. Two six-cylinder diesel engines, rated speed 1,000 r.p.m., each driving a 100-kW, 220-V D.C. generator. Two amplidyne exciter sets, each driven by a compound-wound D.C. motor of 4½ h.p. at 1,500 r.p.m.

As one 200-kW steam set can normally supply all the light and power required, this arrangement gives a large reserve of plant readily available and complete flexibility of generating equipment for any emergency which could arise during steaming, laying, or repairing cables. All six generators are available for parallel operation at constant voltage, and in this condition are normal compound-wound D.C. generators.

Three of these, however, one on each turbine-driven set and the one on the starboard diesel-engine-driven set, are available for use, in any combination, for supplying power to the 300-A constant current circuit which runs the full length of the ship. One turbine-driven set, with one generator on constant voltage and the other on constant current operation, is normally sufficient at sea for cable work. The diesel-driven sets are mainly for use in port when the main boilers are shut down. One set is sufficient for normal lighting, etc., but if power is required in the constant-current circuit both are run, the port machine on constant voltage operation and the starboard on constant current. Being quick starting and economical they are also very useful when the ship is on cable work and one steam set only in use for all purposes, to parallel-in with the machine in constant voltage condition and assist over peak load periods. One only, of the amplidyne exciter sets is used to supply the fields of the generators when on constant current operation, the other being kept in reserve.

Constant current distribution is arranged from a six-panel board (Fig. 1) which, with the exception of the excitation panel, is of the " dead front " type in view of the total voltage, which may reach a figure of 650V maximum. The inboard section is the excitation panel carrying the controls for the two amplidynes, the volt and ampere meters. The following three are the generating panels which are equipped with hand-wheels for changing over the appropriate generators from constant voltage to constant current, by means of switches at the back of the panels. The remaining two, on the outboard end, are the outgoing panels, one controlling the forward section of the series circuit, the other controlling the after-section. The forward section consists of two 160-h.p. motor-driven picking-up and paying-out cable machines and a 100-h.p. motor-driven combined capstan and anchor windlass, while the aft section comprises an 80-h.p. motor-driven paying-out machine and two 45-h.p. motor-driven mooring capstans. The board is provided with a mimic diagram running along the top, which shows clearly the condition under which the generators are operating and the distribution position at the outgoing panels.

The constant current mains and the constant voltage feeders are Pyrotenax cable, which has a mineral insulation and is sheathed in copper. This type of

*Chief Engineer, H.M.T.S. *Monarch*.

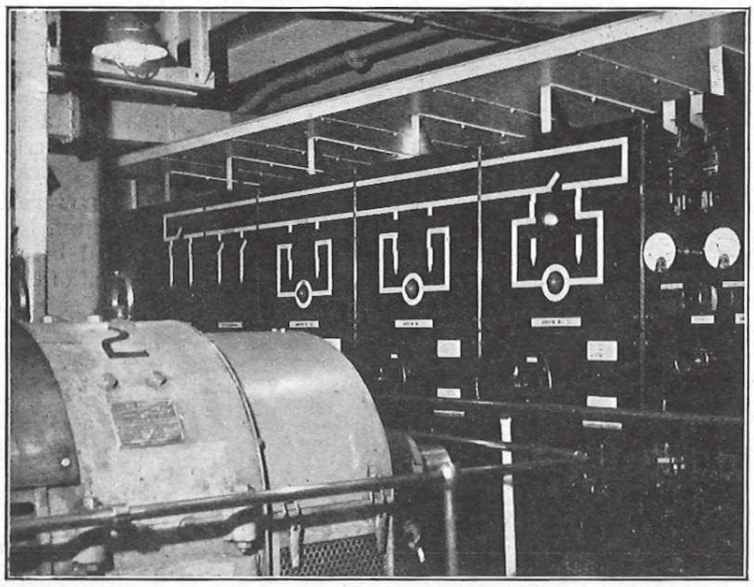


FIG. 1.—THE CONSTANT CURRENT POWER BOARD. MIMIC DIAGRAM SHOWS GENERATOR NO. 3 ON CONSTANT CURRENT OPERATION AND FORWARD DISTRIBUTION IN CIRCUIT.

cable is fireproof, mechanically strong and lends itself to neat and compact layout. The one disadvantage is that the insulating material is slightly hygroscopic and the ends require careful sealing; no trouble has been experienced, however, in practice, from this cause in *Monarch*.

Fig. 2 is a simplified diagram of the power circuit in the ship, showing the amplidyne in use as a constant-current regulator. The amplidyne is a D.C. generator having two poles and two pairs of brushes at right-angles to each other, one pair of which is short-circuited. Unlike the ordinary D.C. generator the main field, instead of being induced by the normal field winding, is set up by currents flowing in the armature through these special cross, or quadrature brushes; the quadrature current is circulated in this short-circuit by inducing a small voltage in the armature between these brushes.

A primary or control field is provided to induce this small voltage but, since only a very low exciting current is required for this field, the control field power is only a fraction of the power required by the field winding of an ordinary D.C. generator. The control field is on the same axis as the armature reaction field caused by the main load current and, since the control field is small, it is essential to neutralise this armature reaction field. To do this, a compensating winding which carries the main load current is provided on the stator. By this arrangement of the fields a very high amplification factor is obtained and, because of the laminated construction of the stator, rapid transient response. The reference field and control field of the amplidyne exciter oppose each other and it is only their difference which is effective.

MOTOR CONTROL AND CHARACTERISTICS

The torque of each motor on the constant current circuit is controlled by adjustment of its separately excited field by the rheostat shown, and the self-excited field stabilises the speed. Contactors, C, allow for cutting each motor in or out of the series circuit, and are interlocked in such a way that the series circuit is never broken. Contactors PU and PO determine the direction of rotation of the motor for picking up or paying out cable. The switches marked SS and IS are respectively the shorting and

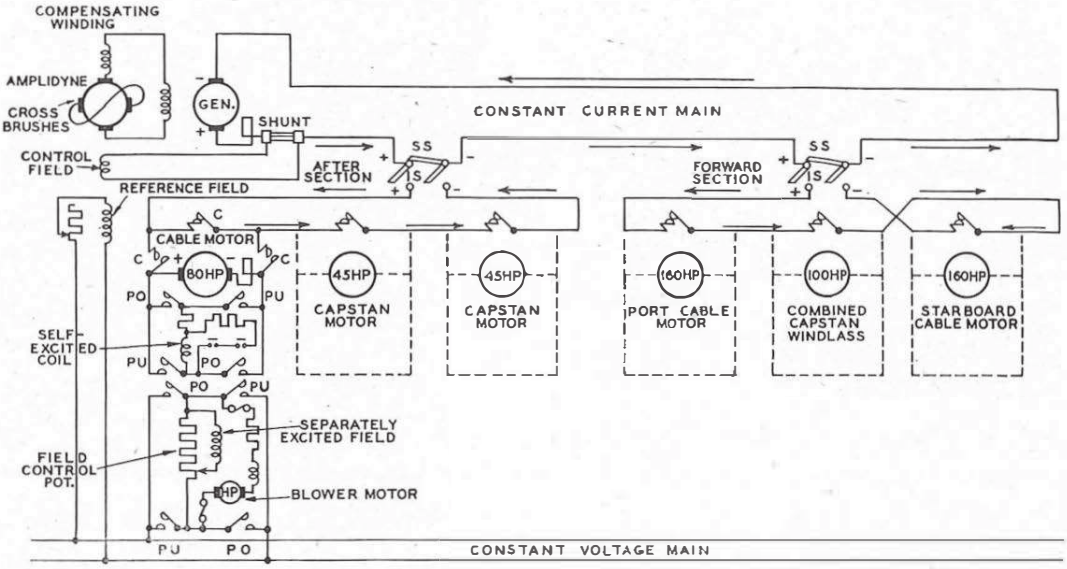


FIG. 2.—SIMPLIFIED CIRCUIT DIAGRAM OF POWER SYSTEM.

isolating switches which control the two sections of the constant-current mains. To prevent accidental open-circuit, SS and IS are mechanically interlocked so that IS must be made before SS can be broken and conversely, when isolating a section, SS must be made before IS can be broken.

The control of the motors as fitted to *Monarch's* cable gear is simple; two mechanically interlocked handles are carried on a ship's telegraph-type pedestal, one handle controlling the direction of rotation and the other torque (and speed). A weatherproof electrical speed indicator panel with pilot lights is mounted close to each controller. With this simple arrangement, a very fine control over the tension in the cable is obtained when picking up with the forward machines. With the armature current held constant at 300A, the motor torque is controlled by varying the field excitation current and can be so adjusted by movement of the torque control handle that the motor will stall at any predetermined weight on the cable. On the load decreasing, as it does in practice, the motor will immediately commence to rotate in the picking-up direction until the load increases to the stalling weight as previously determined.

The following are the mean values of a number of readings taken with a weight of 6·5 tons over the bow sheaves, and the high gear ratio of 57/1 between motor and cable drum speeds:—

Current in armature circuit ..	300A
Minimum field current required to start armature rotating in pick-up direction	4·7A
Equivalent turning effort developed by motor armature	880 lb./ft.

The slightest movement of the control handle to weaken the excitation current below 4·7A when picking up caused the motor to stop. This weight (6·5 tons) is the maximum which can be lifted at this ratio, but a low-speed gear ratio of 227:1 is provided, at which 26 tons can be lifted. With this weight over the bow sheaves the mean values of the readings are—

Current in armature circuit ..	300A
Minimum field current required to start armature rotating in pick-up direction	8A
Equivalent turning effort developed by motor armature	1,200 lb./ft.

The cable drum diameter is 5 ft. 8 in., and with a 2-in. diameter cable the respective cable speeds are 3 knots and 0·75 knot with a motor speed of 940 r.p.m. At these speeds and weights the crane-hook horse power is 134 in both cases.

In earlier cable ships it was common practice not to provide a power drive to the aft paying-out machine. It was often necessary, therefore, to improvise some form of drive, usually from the nearest winch, when starting to lay and before there was sufficient drag on the cable to operate the machine. Wood-lined, water-cooled band brakes acting on cast iron drums were used to regulate the speed of the cable leaving the ship. This type of brake is not smooth in action and is difficult to regulate. An additional air or fan brake, driven by gearing from the drum shaft, was introduced later to improve performance.

Monarch's paying-out gear (Fig. 3) is powered by an 80-h.p. motor coupled to the cable drum by gearing, the ratio of motor to drum speed being 19·8:1. The use of electrical drive in the form of the constant-current system enables this motor to be used in cable laying as a powerful regenerative brake for controlling the cable speed in relation to the ship's speed. By using one of the 100-kW generators for constant current supply and the other for constant voltage, the regenerated power is usefully employed in supplying other electrically operated apparatus in the ship. The motor drive enables the aft paying-out machine to be used, to a certain extent, for picking up cable in addition to its use for paying out before the ship has gathered way and can exert sufficient drag on the cable to move the machine. Electrical braking was originally intended to be alternative, or supplementary, to the older type brakes, which are also fitted, but operating experience has reversed this intention and the latter are now considered supplementary.

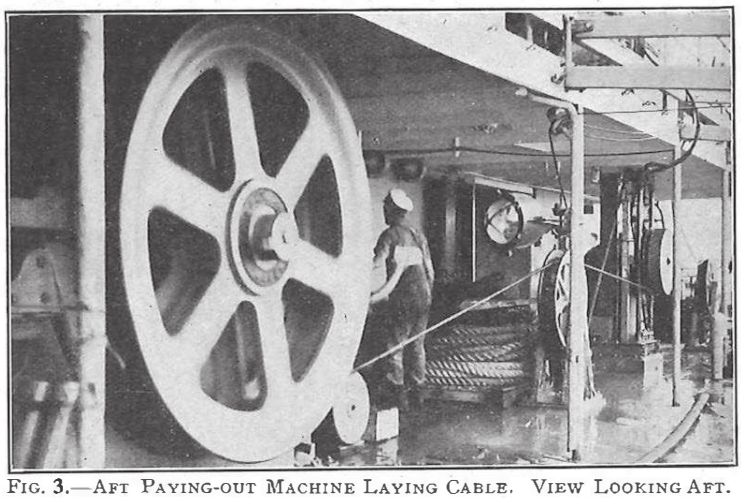


FIG. 3.—AFT PAYING-OUT MACHINE LAYING CABLE. VIEW LOOKING AFT.

TYPICAL LAYING OPERATIONS

In August, 1948, *Monarch* successfully laid 1,120 miles of deep-sea cable between Pernambuco and St. Vincent, 50 miles of which was paid out at the St. Vincent end over the bows in a depth of approximately two miles; the paying-out speed was six knots and the restraint on the cable three tons. The remaining 1,070 miles were paid out over the stern from Pernambuco, commencing at 5 p.m. on the 23rd August and finishing at 2 p.m. on the 30th August, when connection was made with the 50 miles previously laid.

Laying commenced in a depth of 13 fathoms; this

depth increased to over two miles after 50 miles had been paid out and, thereafter, remained reasonably constant between 2 and 2½ miles. The tension/depth graph (Fig. 4) for this particular job shows the ground

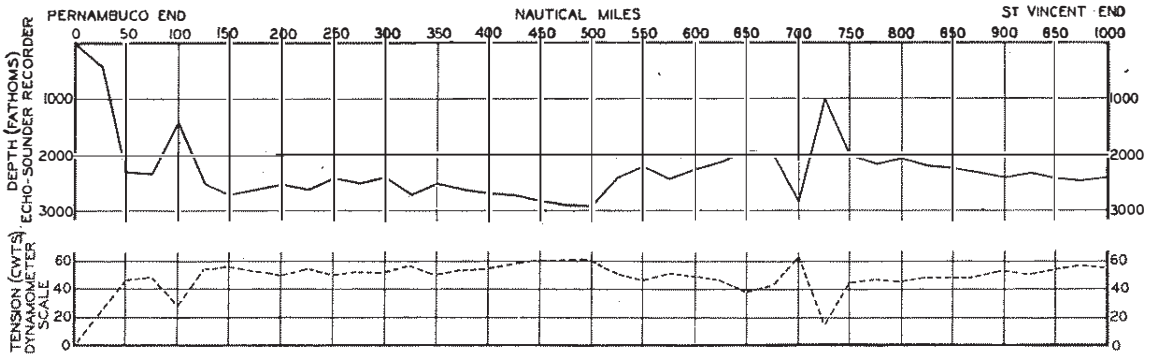


FIG. 4.—GRAPH OF TENSION AND DEPTH FOR ST. VINCENT-PERNAMBUCO RENEWAL IN AUGUST, 1948.

on which the cable was laid. The speed of the ship was kept between 6 and 7 knots, and the cable paid out with an average slack of 7·25 per cent.; the necessary tension in the cable for this was mainly about 2½ tons. The motor speed averaged 700 r.p.m., and the power regenerated at this speed was 42 kW.

At the speed and depth at which the cable was laid, the electrical brake alone was insufficient to regulate the cable speed and the fan brake was used to supplement it, an additional 25/30 h.p. absorption by this means being required to impose the necessary restraint on the cable. The friction brakes were not used except for holding purposes when the ship was stopped to change from one cable tank emptied of cable to a full one. Owing to the liberal rating of the motor of the paying-out machine, it will be possible in the future, by connecting the field coils in series-parallel and modifying the field control potentiometer resistances, to increase the maximum regenerative braking load by about 60 per cent. This will enable all braking to be made electrically, and the use of the fan brake can be dispensed with under normal conditions.

Referring to the depth/tension graph of the Pernambuco-St. Vincent renewal, it will be seen that, because of the difference in scales of depth and distance, a somewhat exaggerated picture of irregularities of the sea bottom is obtained. It shows more clearly, however, the relationship between the depth of the water and the tension applied to the cable to maintain the required amount of slack. Tension graphs for a particular slackness are worked out before commencing to lay a cable, on a basis of 1,000 fathoms depth, and for a range of speeds, usually 4 to 7 knots. Corrections are made for variations above or below this depth and for alteration in speed during the laying operation. Readings of depth, ship's speed and cable speed are taken at half-hourly intervals.

As a matter of interest to readers another typical tension/depth graph is shown in Fig. 5. This was taken from the paying-out log of the Malaga-Las Palmas diversion in July, 1949. As the sea bottom here is comparatively flat with no abrupt peaks or valleys, the cable was laid with a slack of 6·5 per cent. The cable used was recovered in the South Atlantic by the *Monarch* in 1948 and reconditioned by Pirelli at La Spezia; because of difficulty in handling in the cable tanks, it was paid out at the comparatively low speed of 5½ knots. In spite of the reduced speed the electrical braking was quite effective, and a regeneration of about 30 kW was obtained.

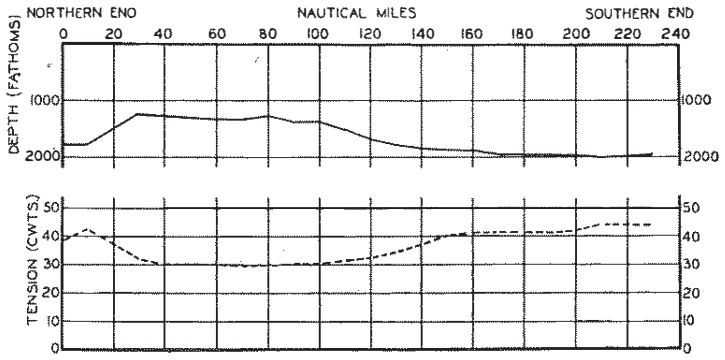


FIG. 5.—GRAPH OF TENSION AND DEPTH FOR MALAGA-LAS PALMAS DIVERSION IN JULY, 1949.

Notes and Comments

Recent Award

The Board of Editors has learnt with great pleasure of the honour recently conferred upon the following member of the Engineering Department :—

Swansea Telephone Area..	de Jong, N.C.C...	Area Engineer..	Major, Royal Signals	The Order of Orange Nassau

Mr. C. E. Moffatt, A.C.G.I., Wh.Ex., A.M.I.E.E.

Congratulations to Mr. C. E. Moffatt, Deputy Chief Regional Engineer, London Telecommunications Region, on his promotion to Staff Engineer, External Plant and Protection Branch, in succession to Mr. P. B. Frost.

Mr. Moffatt entered H.M. Dockyard, as a fitter and turner apprentice, in 1917, and after completing his apprenticeship course, he gained a Whitworth Exhibition and spent a further three years at the City and Guilds Engineering College, London, gaining the Diploma of A.C.G.I.

He entered the Post Office as Probationary Assistant Engineer in 1925. After a short period in the Testing Branch, he was posted to Southampton, remaining there until 1932, when he was transferred to the Technical Section of the old South Midland District at Reading. Two years later he was appointed Sectional Engineer at Reading, and took an active part in the drive for the expansion of the telephone service that resulted from the rate reductions introduced by Sir Kingsley Wood.

In 1938, he was appointed Assistant Superintending Engineer at Bristol and devoted increasing attention to the defence measures then being developed. The war period brought to the South-West Region, as it had then become, a full measure of bombing and he was concerned with the restoration of communications after air attacks on Southampton, Bristol, Plymouth, Exeter, Bath, and many other places. In 1944, followed the urgent tasks of great magnitude that were a prelude to the D-day operations.

In 1946, he was transferred to London as Deputy C.R.E., and was concerned with the arrangements for the reorganisation of the engineering staff of the L.T.R. Since 1947, he has been Chairman of the L.T.R. Amateur Sports Association.

Possessed of a genial personality, an equable disposition, and a sense of humour, Moffatt brings to his new task a sound engineering knowledge and a wide experience. These qualities will ensure his success and all his many friends throughout the L.T.R. and elsewhere wish him well in his new sphere.

W. S. P.

Retirement of Mr. P. B. Frost, B.Sc., M.I.E.E.

On 30th June, the Engineer-in-Chief's Office lost by retirement the services of Mr. P. B. Frost, Staff Engineer in charge of the External Plant and Protection Branch since 1937.

After completing his educational course in Electrical Engineering at the City and Guilds Technical College, Finsbury, and after having spent three years on Workshop Training and one year with the London County Council Tramway Department, Mr. Frost joined the Engineer-in-Chief's Office in 1909.

Experience in the Testing Branch and in the Power and Equipment Branches was followed by five years' service in the first World War as an Officer in what was then the Royal Engineers Signals Service. After a further period of duty in the Equipment Branch, Mr. Frost joined the External Plant and Protection Branch (then the Construction Section) in 1933, and specialised in problems arising from power circuit interference and corrosion. He was made an Assistant Staff Engineer in 1934. His work in this specialised field led to his representing the Post Office at a number of International Conferences (C.C.I.F. and C.M.I.) and to his acting as Chairman of two C.M.I. Investigating Committees. In these capacities he made important contributions to the work of the bodies concerned. His wide knowledge of different branches of Electrical Engineering led also to his representing the Post Office on a number of Technical Committees of the E.R.A. and B.S.I. and on Committees of the Institution of Electrical Engineers.

A modest and charming man, a sympathetic and helpful Chief and colleague, Mr. Frost will be missed as well by the many friends he has made in the office as by those whose contacts have been confined to official matters. It is the earnest wish of all that he may enjoy a long and happy period of retirement. J. L.

The Cable and Wireless Ltd. Transfer

As part of a wide scheme for the reorganisation of Commonwealth communications, the operation of Cable & Wireless, Ltd., services in the United Kingdom was taken over by the Post Office on 1st April, 1950. This has involved the transfer to the Post Office of the Company's main operating station at Electra House, London, their branch offices throughout the country, and the five radio stations at Dorchester, Ongar, Bodmin, Brentwood and Somerton, respectively.

The Post Office now operates the above radio stations direct with points overseas, but cable traffic still passes on to the Company's system at Porthcurno cable station, Cornwall, and the Company continues to operate telecommunication services in all parts of the world, maintaining stations and offices overseas for this purpose.

Of approximately 4,400 of the Company's staff transferred to the Post Office, some 550 have been welcomed into the Engineering Department. We feel sure that our new colleagues will quickly settle down now that the transfer has been successfully concluded, and they may be assured of the hearty co-operation of all engineering staff with whom they come in contact during their official duties.

Institution of Post Office Electrical Engineers

Annual Awards for Junior Section Papers—Session 1948/49

The Judging Committee has selected the following from the papers submitted by the Local Centre Committees, and awards of £3 3s. 0d. and Institution certificates have been made accordingly.

Author	*Junior Centre*	*Title of Paper*
R. T. Ross	Aberdeen	"Aberdeen Trunk Test Rack"
D. G. Elliott	London	"The All-Relay Director"
A. Entwistle, R. A. Gill *	Bradford	"Flexibility in Cable Networks, the evolution of, and observations on the Cabinet and Pillar."

* Award shared

Normally five awards are made, but in view of the comparatively small number of papers submitted on this occasion the Council decided to limit the awards to three.

The Council is indebted to Messrs. W. S. Procter, H. F. Epps and G. S. Berkeley for kindly undertaking the adjudication of the papers forwarded for consideration.

Essay Competition, 1949/50, Results

Prizes of £3 3s. 0d. each and Institution certificates have been awarded to the following three competitors: E. F. Taunton, Technical Officer, Inverness, "The Practical Training of Youths in the Post Office Engineering Department"; J. A. Nash, Technician Cl.II (A), Colchester, "Combined Construction: High Voltage, Low Voltage, and the G.P.O."; L. Gardner, Technical Officer, Prescot, "Some Special Faults Investigations and Clears."

Institution Certificates of Merit have been awarded to: W. H. Elliott, Technician Cl.II (A), Rugby Radio Station, "The methods evolved and difficulties encountered in performing the Acceptance Tests on a W12 Mk. IV Transmitter at Rugby Radio Station"; W. T. Webb, Technician Cl.II (B), Southsea, "Regional Training School"; H. B. Coulthard, Technician Cl.II (A), Carlisle, "Publicity."

J. READING,
Secretary.

N.B.—Particulars of the next competition, entry for which closes on the 31st December, 1950, will be published later.

Regional Notes

North-Eastern Region

FLOODING OF PATELEY BRIDGE EXCHANGE

On 15th February, 1950, a spell of heavy rain, followed by a rapid thaw of the snow on surrounding hills, caused the flooding of Pateley Bridge exchange to a depth of 13½ inches. Water entered the main and local underground cables via the M.D.F. and reached the lower L and K relays and junction relay sets, causing Pateley Bridge U.A.X. 13 and its dependent U.A.X. 12, Ramsgill, to be isolated at about 6.30 p.m.

A mobile U.A.X. 12 from York was taken to the site and connected to the underground cables at a convenient point on higher ground near the exchange. This enabled a temporary service to be restored to 74 of the 137 Pateley Bridge subscribers from 6.30 p.m. on 16th February, 1950. At the same time service was restored to Ramsgill U.A.X. 12 by connecting its three B/W junctions direct to Harrogate N.D. auto exchange. Restoration on a temporary basis was hampered by the fact that a distribution cabinet had also been flooded, and subscribers in the affected cabinet area could not be connected until the cabinet assemblies had been changed.

Fortunately the batteries were only slightly affected, and after recharging by means of the mobile generator they were soon restored to service. It was necessary, however, to renew all the underground cables from the M.D.F. to a nearby joint as the water had run back down the cables for a distance of six or seven yards. For the permanent restoration, it was decided to replace all individual items damaged by water and to dry out the internal wiring by using a concentration of heat, vacuum-cleaner attachments, fans and hairdriers. By working day and night shifts, and with concentrated effort, it was possible to complete the work and restore a full service on the original exchange by 2.30 p.m. on Sunday, 19th February, 1950.

Although a flooded-area type building had been erected, and the floods were the highest in the district for about 25 years, it was thought that precautions should be taken to minimise the risk of future flooding. The method adopted was to raise the whole of the U.A.X. equipment (four A, five B and one C Units) by 12 in., i.e. the maximum distance above the Units to the roof cross-members. U-shaped lifting brackets were made from 3 in. × 1 in. mild steel and passed under each Unit in the row. The brackets were then each bolted to two 4 in. × 4 in. H-iron girders, one at each side of the row of Units. Eight car-type lifting jacks were used, four at each side under the H-iron girders, and the Units lifted 6 in. The Units were then supported on sleepers and the lifting tackle transferred to the other row of Units.

It was necessary to complete the lift in stages of 6 in. because of the limit imposed by the cables connecting the C Units to the B Units. The play of 6 in. was obtained by unbolting the cable trough and breaking the gasket between the trough and the B Unit. The Units were finally supported on 12 in. × 6 in. H-Section iron girders, a short length of which was placed under the feet of each pair of Units. The lower row of secondary cells, the charging rectifier and the Power Company's meter and fuses were also moved to positions well clear of any further probable flood level. T. J.

EXPERIMENT IN KIOSK ERECTION

In order to reduce ineffective costs in travelling to decorate kiosks erected on site, especially in rural areas, it was decided to assemble and decorate kiosks at a central point. A suitable building where this work could be done under cover was chosen, since this eliminates any loss of time due to bad weather.

As the weight of an assembled kiosk is about one ton, it was obvious that a three-man kiosk party could not load and unload the kiosk without either additional assistance or some mechanical aid. The use of additional manpower would have reduced the overall saving and, therefore, it was necessary to produce a mechanical aid. Various methods were considered and in the final arrangement the method of operation is as follows :—

(1) kiosk, derrick, vehicle and lifting tackle in position ready to start loading.
(2) kiosk lowered on to a roller fitted at rear end of the vehicle floor.
(3) kiosk raised to a horizontal position, as shown in the illustration. Weight taken on rear roller.

KIOSK LOADING OPERATION.

(4) derrick and kiosk moved forward. Kiosk weight now taken on rear and forward rollers.
(5) kiosk in final carrying position, derrick loaded and operation complete.

Unloading is the reverse of the above procedure and, if necessary, the kiosk can be unloaded on to a flat trolley which has been made for the purpose of moving the kiosk in awkward places. In the majority of cases, the vehicle can be backed to the actual site.

The general procedure is for three men to assemble a number of kiosks. Two of the men then travel to the sites and prepare bases whilst the third man decorates the assembled kiosks. When bases and kiosks are ready the three-man party erects the kiosks. In using this method in the Middlesbrough area, the average saving has been 15 manhours per kiosk.

The derrick was constructed from angle and channel iron in the local workshop ; it has already proved of use in handling U.A.X. Units and could also be of use in lowering loading coils into manholes, etc. E. R. T.

Scotland

CABLE-LAYING ON A GOLF COURSE

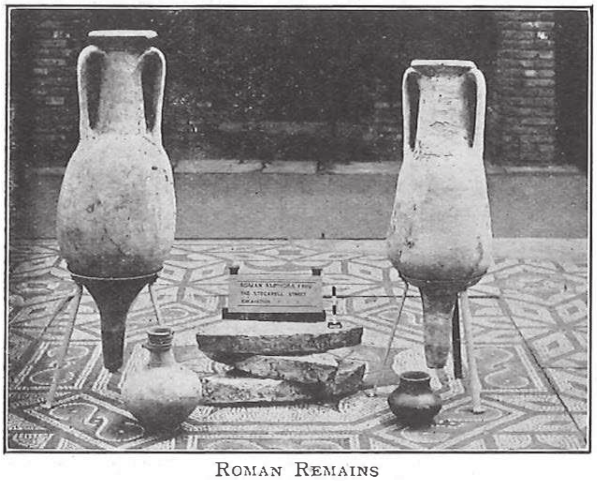
Occasion arose in April to lay a cable across two fairways of the Old Course of the Royal and Ancient Golf Club, St. Andrews, and the standard mole drainer equipped for feeding in cable behind the blade was used. As the course had been closed for a month to get it into perfect condition for the Amateur Championship, it was with some trepidation that the job was tackled, as a scar across that sacred turf on such an occasion would have caused much heartburning. However, the job was done, and the almost complete absence of any mark afterwards is the excuse for mentioning the matter here, as it was not realised that such a perfect reinstatement could be effected on cultivated grass. While the main closing of the slit was carried out by a heavy roller, it was found desirable to close it partially by foot pressure before putting the roller over it to avoid a slight turning of the sod and distortion of the edges. The job was completed by brushing the track with a stiff brush.

Home Counties Region

ROMAN REMAINS AT COLCHESTER TELEPHONE EXCHANGE

Colchester (Camulodunum) is one of the oldest, if not the oldest, recorded town in Britain ; and the decision to enlarge the telephone exchange building by an extension in the rear, and at the same time to construct a deep basement, was of immediate interest to the archæological world. The approximate design of the Roman town of Camulodunum, with its chequerboard layout of parallel streets running North to South and East to West, was known, and it was anticipated, that one of the streets would run through the portion of land which would have to be excavated.

Arrangements were made by the Ministry of Works, who were in charge of the building work, for the soil to be very carefully removed and hand-sorted so that nothing of archæological interest which had a bearing on life at the time of the Roman occupation of Britain should be lost. The excavations commenced in January, and the expected Roman street was early in evidence with layers of shingle down to a depth of eight feet, along with plentiful supplies of the well-known Roman bricks.



ROMAN REMAINS

About six feet from the surface was the layer of burnt earth, a significant reminder of the troubles of the town in the year A.D. 61, when Queen Boadicea and her tribesmen of the Iceni stormed the town, exterminated the garrison, burned everything to the ground and swept on to the South. From that level to a depth of about ten feet were the remains of the walls of buildings on both sides of the street, with the pediments of gate-posts which must have been connected with buildings of considerable size. Portions of marble facings were also found along with quadrant-shaped tiles which were used, when placed in fours, to form sections of round pillars. Deep down in one corner of the excavation, side by side and embedded in the soil, were found two amphoræ or wine jars of the type used to convey wine from Italy to Britain. These, as illustrated, were almost perfect, and were considered by the authorities to be very fine specimens; they are now on show in the museum at Colchester Castle.

Many portions of pottery—from the fine decorated Samian ware to the crude locally-made varieties—were found, dating from the first Roman occupation, but only a few coins, although among them was one of Antonia, the wife of the Emperor Claudius, who captured Colchester in the year A.D. 43. Very deep in the excavations was found the skull of a wild boar in such a state of completeness that it will enable experts to build up a very good idea of the creature which roamed around the area in the very early days. H. C.

PROTECTIVE MEASURES ON MAGDALEN BRIDGE, OXFORD

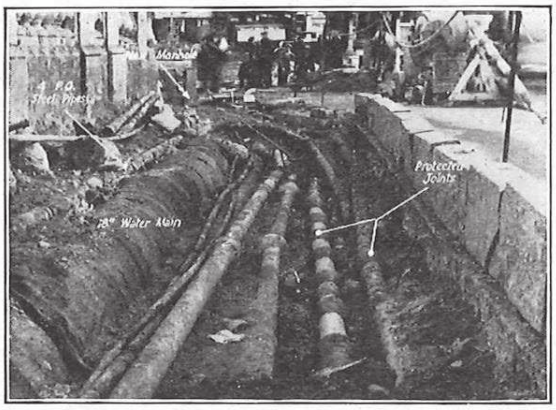
Magdalen Bridge is the principal means of approach to the centre of Oxford from the east, and this, with its historical and sentimental values, has made the preservation of the bridge a matter of more than local importance.

Concern has been felt for many years over the steady deterioration of the original stonework and the gradual disintegration of the mortar from the keystones. When it was discovered in the summer of 1949 that subsidences had occurred under the numerous service pipes passing over the bridge, the Borough Surveyor arranged for the water-proofing of the bridge as a matter of urgency, and it was decided to use a high-pressure cementation process whereby the bridge would be water-proofed and strengthened simultaneously. This process is intended to fill all voids and cavities in the arches and columns with cement and entails drilling holes of approximately 1 in. diameter at yard intervals in the road surface through which water is injected to wash out loose material including any disintegrated mortar. This is followed by a thin grout which is thickened up as the pressure increases until penetration through the immediate area of the bridge is secured.

It was felt that unless protective measures were undertaken the various service pipes would inevitably become blocked by the entry of the grout, and it was ascertained by piloting that no space for additional pipes was available. Ten Post Office steel and cast-iron pipes of various sizes and ages pass over the bridge together with one S.A.D., and a number of important trunk and junction cables as well as local cables are carried in them. Ten of these are situated under the north footway together with an 18-in. water main, two gas mains and electricity cables, all being confined within a depth of 19 in. over the main arches. Although the number of Post Office pipes was considered adequate for future requirements, it was known that certain old types of coupling existed at various places on the bridge and it was thought that vibration would inevitably have affected a number of joints, and that various cracks and defects might exist. At such points the liquid grout would penetrate and result in blockage of the pipes and

corrosion of the cables and prevent the essential recovery of a number of older cables, even if it did not penetrate to the manholes at the ends of the bridge.

It was decided therefore to expose all pipes over each of the arches and carry out protective measures at points where danger existed. Each joint was covered with two wrappings of hessian tape and a cement collar placed around the taped joints. These joints can be seen



EXPOSED PLANT, INDICATING PROTECTION.

in the close-up view of the protective measures. In all, approximately 270 joints were concerned and the work spread over two months.

The work naturally presented certain difficulties from a contractual viewpoint. As each of the other Services concerned—water, gas and electricity—had also decided upon protective measures, proposals were made for one contractor to carry out the whole of the work and amicable arrangements made for the apportionment of the costs between the various authorities. By the co-operation of all parties, the contractor was enabled to commence work sufficiently in advance of the cementation process to ensure that the bridge work was not delayed. At the time of writing, the protective measures on the north footway are completed and the cementation process is proceeding steadily. No evidence of grout penetration exists, but the success of the measures will not be finally known until the process of recovery and renewal of the cables is completed later in the year.

The operations on the bridge have been complicated by the coincident construction of a roundabout in place of an old burial ground at the east end of the bridge. It has been necessary to carry out certain advance ductwork in conjunction with these operations and to abandon two old pipes passing through the centre of the roundabout. It has been found possible to divert these pipes into a new manhole and commence a programme of cable renewal, which it is hoped, will ensure a sufficient number of spare ways being available over the bridge for future requirements and will simplify some of the cable maintenance problems at this point in the Oxford network.

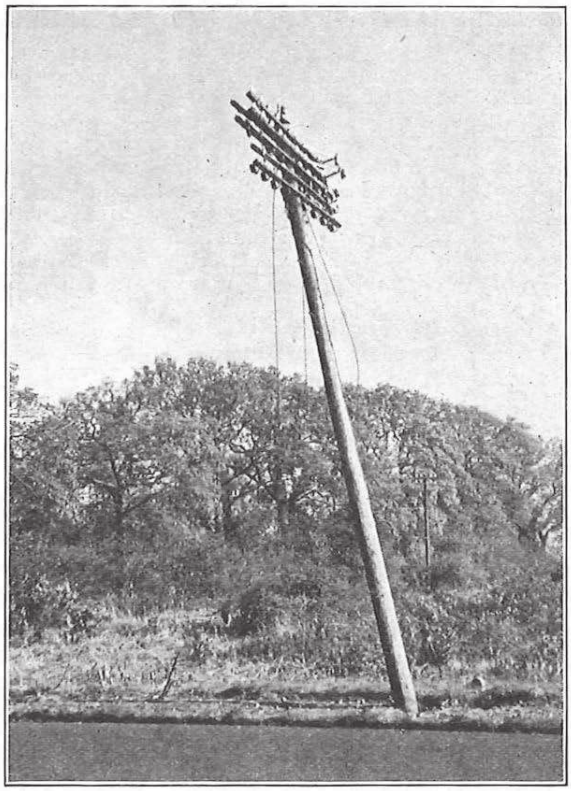
K. W. H.

SEVERE STORM DAMAGE

The wintry spell in the latter part of April culminated during the night of the 25th/26th in a sudden, short but heavy fall of snow which caused widespread havoc to open wires and poles in an area extending from Maidstone to beyond the border of the South-West Region, and from Ascot to Petersfield, Horsham and East Grinstead. There was also damage over much of the southern territory of the London Telecommunications Region.

The snow was of a heavy wet variety and there was sufficient frost in the air to cause the snow to stick to the wires and build up " ropes " of 1 in. to 2 in. diameter within two or three hours. Railway routes also suffered seriously and overhead power supplies to a number of exchanges and carrier stations were interrupted for a day or so.

Some 24,000 subscribers' lines were put out of order, the whole of the Guildford Telephone Area being seriously affected to the extent of 14,200 lines out of a total of 36,000. This varied from 50 per cent. out of order in the Basingstoke Maintenance Control territory to 25 per cent. in that of the Dorking Control. The damage was similarly severe in the Sevenoaks Maintenance Control of the Tunbridge Wells Telephone Area, with some 45 per cent. of the lines affected; in fact the impression gained in and around Sevenoaks was that hardly a span remained where the wires were intact and in good regulation, and relatively few poles were not pulled from upright. One of the photos shows typical damage to subscribers' lines. Parts of the



TYPICAL DAMAGE TO D.P. AND SUBSCRIBERS' LINES.

Canterbury, Reading, Portsmouth and Brighton Telephone Areas were also involved, but to a less widespread extent and by heavy concentration of effort were cleared within 10 days.

Pole breakages to a total of some 580 occurred, practically all falling in line with the route rather than at right angles since there was very little wind. The most spectacular breakages occurred on an " H " pole route between Sevenoaks and Tonbridge, as illustrated. Twenty-five such poles broke, but where no strut existed the breakage was generally at ground level. Similarly a heavy route between Basingstoke and Aldershot, containing wires up to 400 lbs., was down over much of

the distance, with poles and wires lying on the grass verge. Most of the wires were due for recovery, but the residual junction and subscribers' circuits necessitated the use of interruption cable pending underground or

Reproduced by courtesy of "Tunbridge Wells Advertiser"

BROKEN H-POLE BETWEEN SEVENOAKS AND TONBRIDGE.

aerial cabling and opening new D.P.s. The great majority of broken poles showed no sign of decay.

Where D.P.s were broken, especially where forming part of an old heavy route, opportunity was taken in suitable cases to restore service by an increased number of D.P.s, mainly of the ring type. In general, where 10 or more wires were down for more than a few spans, interruption cable was laid, and in the great majority of cases was replaced by aerial cable as quickly as stores came to hand. About 60 miles of interruption cable was used. For the smaller routes and subscribers' drops the aim was to reset the poles and re-regulate the wires from the outset, temporary work being reduced to a minimum. Much work still remained, however, even after service had been restored, on routes where wires were slack but not damaged enough to put the subscribers out of service. In most cases stretched wires were pulled up rather than renewed, though renewal was involved later in some instances where the fault incidence showed this to be necessary.

The effect of this freak fall of snow was greater than can be recollected from any previous storms in the particular localities, and with 40 per cent. of the subscribers affected in the Guildford Area, and a similar proportion in the northern part of the Tunbridge Wells Area, it will be appreciated that restoration of even temporary service was bound to take a considerable time, even with a large influx of additional gangs. Fifty-seven gangs were loaned to these two Areas, including 31 on a daily travelling basis from nearby centres in the surrounding Areas of the H.C. and L.T. Regions. The acute difficulty of finding lodgings for gangs was a limiting factor, and some were accommodated in P.O. staff rooms and a military camp. Military assistance on a small scale was also obtained and in the Guildford Area it is notable to record the voluntary assistance of clerical, draughtsmen and sales staff at week-ends for clearing and coiling tangled wire from farm entrances, etc.

After three weeks the number of subscribers out of service was reduced from 24,000 to 1,300 and restoration to all subscribers, including those in the most isolated localities, followed within a further week. All the staff concerned were, of course, working very long hours and they responded with that extra keenness and enterprise which they always show at such times of emergency.

R. O. B.
H. M. W.

Welsh and Border Counties Region

SWANSEA EXCHANGE—MAJOR EXTENSION

The Swansea zone centre exchange (Siemens No. 16 equipment) was installed in 1924, and is believed to be the oldest of its type in the country. Due to the increase in trunk traffic and the subscribers' waiting list it was necessary to provide relief prior to the new building programme; this involved a general shift of the telephone exchange and repeater equipment and power plant to provide sufficient accommodation to meet the needs of a fairly large extension.

The major portion of the accommodation to be made available was on the second floor of the Head Post Office, which already housed the Swansea repeater station, two 60-volt 2,200 ampere-hour batteries, and welfare room. It was necessary to provide a new repeater station, located two miles from the main exchange. The question of the long 2-wire ends on trunk circuits had already been taken into account by providing 4-wire terminations in the basement of the Head Post Office. In addition to this, all the M.U. cables were intercepted in the cable chamber and terminated on test tablets, the back ends being used as ties for the purpose of carrying the short two-wire ends to the trunk equipment. The interception of the Carmarthen-Swansea cables, etc., and the provision of a 494 + 4/40 screened cable between the new repeater station (SX/B) and the basement repeater station (SX/A), provided for sufficient 4-wire circuits to Swansea.

The shift of the main auto battery was carried out by the contractor with no interference to the service. Each box had to be emptied of acid and lead plates and transported separately by using a separate container secured in a suitably designed cradle for lowering externally by the use of jib and tackle. In the course of removal, it was found that the lead linings of 10 boxes were prone to leaks. The contractor was unable to provide new boxes immediately but, as a temporary measure, 10 submarine-type cells of equivalent capacity were supplied as substitutes.

The removal of 2 motor generators, associated bedplates and filter, weighing approximately 5 tons, from the third floor to the basement, was carried out by contract. Careful organising and manipulative skill ensured the successful operation of the work without interference to the service. The space made available has been used to accommodate two suites of 60-volt sleeve-control switchboards of 21 and 14 positions dealing with demand and incoming traffic, respectively. The vacated bridge control trunk suite is being rearranged to provide 13 additional toll positions.

It is envisaged that the additional trunk and toll positions will meet the traffic demands for several years. Since approximately 80 per cent. of the circuits are jointly accessible to both suites, bridge- and sleeve-control relay sets are used in conjunction with joint access equipment, and free line signalling on the new trunk suite works jointly with the existing visual engaged signal on the bridge-control toll suite. These facilities, plus the fact that two separate I.D.F.s (viz. trunk and toll) have to be taken into account, make jumpering of circuits and fault location work a complicated process. Staff concerned were, therefore, instructed during execution of the contract.

The provision of a 7-position test desk and associated test jack frames has eased the maintenance control congestion considerably and greater efficiency can now be attained.

To meet the subscribers' development and, at the same time relieve the load on the main exchange switching equipment, an additional satellite exchange, using 2,000-type discriminator equipment, is in course of installation. The introduction of 2,000-type equipment necessitated provision of additional switching equipment and relay sets at Swansea exchange in order that conversion of battery and loop dialling between Siemens 16 and 2,000-type exchanges could be effected. Similar provision has been made for the conversion of other satellites to 2,000-type, and to obtain space for this equipment, approximately 500 subscribers' calling equipments were recovered and the subscribers affected transferred to other equipment.

It was inevitable that the considerable rearrangements and new work, and building alterations, should cause some temporary deterioration of service and throw much extra work on to the maintenance staff. Great efforts are being made by all concerned to restore to normal conditions and the contractor is to be congratulated on the successful organisation of an involved series of operations which are now approaching completion. T. J. D.

Junior Section Notes

Birmingham Centre

The Annual General Meeting was held on 4th April, 1950. A brief review of the 1949-50 programme was read and the strength of the Centre was reported as 139. An interesting programme formed on the members' desires was carried out, and again visits were very popular.

The Centre's library has been gradually reformed, after total loss by enemy action during the war, and it contains a good selection of reference papers, correspondence courses, Journals, etc., and a healthy circulation of technical periodicals has been set up by the librarian. It was decided to strengthen this by purchase of further periodicals out of the Centre funds, as well as using those passed in to us by the Senior Section.

The Centre is still without a room for use by members as a library or reading room, due to accommodation difficulties in the Area, but it is hoped that we shall eventually secure a suitable room.

It is hoped that a larger number of members will take a more active part in the Centre's activities in the new session.

Officers and committee elected for 1950-51 at the Annual General Meeting :—

Chairman : K. G. S. Adams ; *Hon. Secretary :* E. H. Cinderey ; *Hon. Assistant Secretary and Librarian :* E. Bird ; *Treasurer :* J. Cockhill ; *Committee :* F. Carpenter, B. Headley, F. Windsor, H. Harper, R. Morris, L. Oliver, W. Johnson ; *Auditors :* G. Crockett, A. Whitlock. E. H. C.

Bournemouth Centre

The 1949-1950 session commenced in October after a lull in our activities. Some doubts existed as to whether or not our colleagues would support us, but we are pleased to say our fears were soon dispelled. The first lecture was given by Lt.-Col. F. A. Hough, M.B.E., M.Sc., A.M.I.E.E., on the subject of "Area Power Plant," during which the design principles of various types of motors were demonstrated by ingenious models of his own design. The following month one of our members, Mr. R. J. Matterface, gave a lecture entitled : "The Introduction of Automatic Telephones in the Bournemouth Area." Considerable interest was shown in this subject, because of the recent conversion of manual exchanges in the Bournemouth multi-office area.

In the new year our Area Engineer, Mr. E. S. Rusbridge, gave a talk summarising future national and local engineering developments. The questions which followed displayed keen interest in plans for the new Bournemouth main automatic exchange, and the effect on the local engineering programme of the reduction in Post Office expenditure. We then adjourned to inspect an exhibition of hobbies. The exhibits ranged from steam engines and chiming clocks to lampshades and embroidered table cloths, which shows the wide variety of talent of our colleagues.

In February we had a lecture and demonstration on "Television" by a member of the Field Research Unit of Messrs. Scophony Baird, for which we had a record attendance. The interesting discussion which followed indicated the deep interest taken in this topic and the many problems met by our television experimenters. The March meeting took the form of a Technical Challenge Quiz with our Bristol colleagues ; the proceedings were conducted over land lines, resulting in a win for Bournemouth by two points. The answers emphasised the high technical standard of the teams, both of whom were skilfully handled by their respective Quiz Masters. Our Telephone Manager, Mr. W. R. Tyson, occupied this position at Bournemouth and produced much amusement with his witty remarks on how a Post Office cat is provided and maintained, a question submitted in lighter vein.

The lectures for this session have now been completed, and we are commencing a series of visits. The first took place on 15th April when we visited the Pirelli General cable works. This visit proved most instructive, and we were impressed by the complex machinery and efficient organisation which exists for providing power and telecommunication cables.

Our membership has now risen to 100, and we expect to improve on this. The past year has proved very encouraging and we hope has stimulated sufficient interest to bring forth more papers and new items for our 1950-51 session. F. T. G.

Darlington Centre

On the 16th February several members journeyed to Middlesbrough for the President's meeting, and participated in the discussion which followed Mr. Harbottle's talk. All voted the meeting most enjoyable.

The Centre completed the 1949-50 programme on 28th March with a talk—"The North-Eastern Electricity

Board"—brought forward from 7th March, due to the speaker's inability to attend. The speaker was Mr. T. E. Daniels, M.Eng., M.I.E.E., M.I.Mech.E. (Chairman of the N.E. Electricity Board), and his talk proved to be worth waiting for. The meeting attracted a good attendance of members and visitors, amongst whom were the Chief Regional Engineer (Mr. W. F. Smith), the Area Engineer (Mr. A. C. Pitcairn) and the Head Postmaster (Mr. C. O. Thomas). Mr. Daniels described, in a most illuminating manner, the generation of electricity, the grid system and the Board's administration. A most enthusiastic discussion followed, in which members and visitors took part—a salvo of 23 questions was fired at the speaker, who answered them in a most able manner. The vote of thanks by Mr. R. W. Cowen was endorsed by the C.R.E. and applauded by all present.

At the General Meeting on 18th April the Secretary reported there had been a membership of 70 for the session, with an average attendance of 31 at the meetings. The Committee were pleased that the programme had met with general approval. The Central Library had not been so well patronised, but there had been numerous requests for the Courses held by the Centre.

As no members had submitted written papers prior to their talks, they could not qualify for the National Competition or the C.R.E.'s prize.

A suggestion received from the Council of the Institution that a "Forum" should be set up in the Junior Section notes of the Journal was commended by the Centre Committee as it was likely to lead to an exchange of views with other Centres.

The offer of a prize by the Telephone Manager (Colonel J. R. Sutcliffe) for the best talk given by a member of the Darlington and Middlesbrough Centres was acknowledged as a fine gesture.

The statement of accounts, read by Mr. B. Midcalf, proved most interesting.

Officers elected for the Session 1950-51 are :—

Chairman : E. Pinkney ; *Vice-Chairman :* B. V. Northall ; *Secretary :* C. N. Hutchinson ; *Treasurer :* B. Midcalf ; *Committee :* N. V. Allinson, G. C. Beggs, R. W. Cowen, J. Cochrane, P. Dodd, G. A. Garry, T. L. M. Hebron, H. G. Midcalf, A. F. Millar, A. Snowden. *Auditors :* D. E. Dodds and J. D. Benhamin.

The Membership fee was fixed at 1s. 6d. for the 1950-51 session.

C. N. H.

Dundee Centre

The 1949-50 session was brought to a close on the 18th April, when Mr. Paterson, of the Scottish Information Office, presented the following films :—

"Electrical Generation," "Electro-Magnetic Induction," "Precisely Yours," "Wonders of the Deep," and "In all Weathers."

The meetings have been well attended, and the final membership reached a total of 81.

The committee thank all members for their support and hope to see them again in the 1950-51 session.

D. M.

London Centre

This session, 1949-50, can be recorded as the most outstanding in the history of the Centre. The membership is now 2,500, an increase of 500 over last year's figures, and there is no doubt that deductions from pay have assisted in this matter, for which thanks must be extended to the old members of the London Centre Committee who have throughout the years advocated this principle.

The Programme for 1949-50 has been extremely interesting. The Lectures given and papers read have been very instructive, and it is a pity that so many members fail to avail themselves of these advantages. It is hoped that two papers will be presented to the Senior Section's Competitions, for their annual awards. All Area Representatives and local committees have excelled themselves in the way they have presented and arranged their lectures, debates and visits. They have carried out their responsibilities well.

The use of the Senior Section Library has been very beneficial to all members, and their Periodicals, augmented by those purchased by the London Centre, have had a wide circulation.

An innovation in three Areas, West, North and Long Distance, has been the introduction of Radio Sections. These Sections deal primarily with the construction and maintenance of home-built Television and Radio sets. Members can also purchase component parts at reduced rates. Praise for the original idea should be extended to Mr. L. W. Evans, West Area.

Many Areas are taking advantage of the method whereby a percentage of their Members' Yearly Subscription is returned to them to help with local activities.

Owing to the late delivery of the 1950 Diaries, a financial loss has been incurred. However, for the 1951 Diaries, we have an assurance from the publishers of an earlier delivery.

A Committee, presided over by the General Secretary, Mr. A. W. Lee, has for the past six months been compiling an I.P.O.E.E. Junior Section Handbook containing data relative to Telecommunications. A novel feature of this Handbook will be its simplified index. It is hoped to present this book to the Committee during the 1950-51 session. In this respect, thanks must be extended to Mr. A. E. Penney, our Liaison Officer, for his offer to submit the material contained in the Handbook, to the various experts within the Engineering Department, for verification of its accuracy.

The Centre Committee wishes to record its thanks to our Senior Section Liaison Officer, Mr. A. E. Penney, for his steadfast help during the Season. The Committee also wish to take this opportunity of expressing their high appreciation of the energetic assistance given at all times by our Secretary, Mr. A. W. Lee. On account of the transfer to another position within the Department, of Mr. E. L. Tickner, the Centre lost one of its most valued members. During his twelve years of service as Member, Secretary and Chairman, of the Committee, he always set a very high standard of duty, and has left behind him a great tradition which it will be hard to maintain.

Finally, I am pleased to record a sound financial position of the London Centre of the Junior Section, and this is a very good augury for the future.

On behalf of the London Centre Committee, may I, as Chairman, express our deep appreciation to all the lecturers, the Senior Section, and the Department, for their valuable assistance, and to all others who have in any way helped in the smooth running of the Centre.

A. G. W.

Middlesbrough Centre

The Annual General Meeting of the Middlesbrough Centre took place on Thursday, 20th April. The following officers were elected for the 1950-51 session :—

Chairman : D. Paterson ; *Vice-Chairman :* C. Allison ; *Secretary :* J. Brown ; *Vice-Secretary :* R. R. Johnson ; *Treasurer :* K. Lynas ; *Auditors :* N. F. N. Bennett, A. Bonnier ; *Committee :* J. C. Hall ; G. A. Buckle, H. D. Sloan, J. Mansfield, E. E. Sparkes, D. B. Sawyer, W. Burke.

The 1949-50 session proved to be a great success—figures showed a marked increase in attendances. The

(*Continued on page* 116)

Staff Changes

Promotions

Name	Region	Date
Engr. to Exec. Engr.		
Wooding, W. T.	L.T. Reg.	1.3.50
Winterborn, E. E. L.	E.-in-C.O.	26.2.50
Stone, M. C.	S.W. Reg. to E.-in-C.O.	19.3.50
Alston, G. J.	N.W. Reg. to W.B.C. Reg.	1.4.50
Hopkinson, E.	N.E. Reg.	26.2.50
Todkill, H.	E.-in-C.O. to Mid. Reg.	1.3.50
Pooley, E. H.	H.C. Reg. to Mid. Reg.	5.3.50
Mitchell, C. W. A.	E.-in-C.O.	1.3.50
Walker, D. C.	E.-in-C.O.	14.2.50
Bampton, J. F.	E.-in-C.O.	14.2.50
Truslove, E. H.	E.-in-C.O.	14.2.50
Engr. to Reg. Tng. Off.		
Hood, J. B.	Mid. Reg.	12.4.50
Prob. Engr. to Engr.		
Gauntlett, R. D.	E.-in-C.O.	2.2.50
Ridlington, A. D. V.	E.-in-C.O.	16.3.50
Aspinall, C.	E.-in-C.O.	1.5.50
Bellew, T. K.	E.-in-C.O.	5.5.50
Billinghurst, F. M.	E.-in-C.O.	31.5.50
Chick, P. G. S.	E.-in-C.O.	24.5.50
Hamer, R.	E.-in-C.O.	1.5.50
Hesketh, J. F.	E.-in-C.O.	1.5.50
Kyme, R. C.	E.-in-C.O.	1.5.50
Manning, D. J.	E.-in-C.O.	31.5.50
Orchard, H. J.	E.-in-C.O.	1.5.50
Williams, J.	E.-in-C.O.	24.5.50
Williams, M. B.	E.-in-C.O.	1.5.50
Faulkner, E. B.	E.-in-C.O.	1.5.50
Parker, P. N.	E.-in-C.O.	1.5.50

Name	Region	Date
Prob. Engr. to Engr.—continued		
Holden, R.	E.-in-C.O.	10.5.50
Benton, G. C.	E.-in-C.O.	31.5.50
Irwin, A.	E.-in-C.O.	1.5.50
Burley, N.	N.E. Reg.	18.5.50
Boxall, T. R.	E.-in-C.O.	1.5.50
Asst. Engr. to Engr.		
May, R. H.	N.W. Reg.	1.4.50
Bryant, J. W.	N.E. Reg.	23.4.50
Waterhouse, L. R.	N.W. Reg.	1.4.50
Hunter, W. J.	N.E. Reg.	1.4.50
Waterman, L. R.	L.T. Reg.	11.4.50
Jones, C. W.	N.W. Reg.	1.5.50
Rayns, F. H.	E.-in-C.O.	1.4.50
Dawson, C. F. O.	L.T. Reg.	1.4.50
Richards, P. W.	Mid. Reg.	1.4.50
Cullen, W. E.	L.T. Reg.	1.4.50
Wright, H. C.	E.-in-C.O. to L.T. Reg.	26.4.50
Winkley, W. J. F.	H.C. Reg. to E.-in-C.O.	23.4.50
Morgan, J. L. W.	E.-in-C.O.	1.4.50
Dorner, D. J.	E.-in-C.O.	1.4.50
Tech. Off. to Asst. Engr.		
Slade, W.	E.-in-C.O.	1.4.50
Bullen, W. L.	E.-in-C.O.	1.4.50
Barker, W. V.	E.-in-C.O.	1.4.50
Pearson, P. R.	E.-in-C.O.	1.4.50
S. Sc. O. to P. Sc. O.		
Lynch, A. C.	E.-in-C.O.	22.4.50
Shotton, D. C.	E.-in-C.O.	28.10.49

Transfers

Name	Region	Date
Exec. Engr.		
Hawking, W.	W.B.C. Reg. to N.E. Reg.	1.4.50
Hoare, E.	N.E. Reg. to H.C. Reg.	1.4.50
Jones, C. E. P.	E.-in-C.O. to L.T. Reg.	1.5.50
Tucker, D. G.	E.-in-C.O. to Admiralty	1.4.50
Engr.		
Conn, C. A.	E.-in-C.O. to S.W. Reg.	12.3.50
James, L. R.	S.W. Reg. to L.T. Reg.	19.3.50
Horton, G. P.	E.-in-C.O. to Admiralty	5.3.50

Name	Region	Date
Asst. Engr.		
Goymer, E. G.	E.-in-C.O. to Australian P.O.	2.3.50
Bennett, F. G.	L.T. Reg. to E.-in-C.O.	6.3.50
James, N. S.	E.-in-C.O. to W.B.C. Reg.	24.4.50
Kelly, F.	E.-in-C.O. to N.W. Reg.	30.5.50
Sen. Sc. Off.		
Hansford, R. N.	E.-in-C.O. to Admiralty	1.5.50

Retirements

Name	Region	Date
Asst. Staff Engr.		
Ellson, F. A.	E.-in-C.O.	30.4.50
Area Engr.		
Robinson, R. P.	H.C. Reg.	31.5.50
Langford, L. C.	L.T. Reg.	28.2.50
White, J. A.	H.C. Reg.	31.3.50
Arnold, W. H.	Scot.	30.4.50
Engineer		
Blewitt, E.	S.W. Reg.	31.3.50
McDougald, F. M.	N.W. Reg.	31.3.50
Brown, A. H.	Mid. Reg.	10.3.50
Brock, W. P.	L.T. Reg.	31.3.50

Name	Region	Date
Engineer—continued		
Howarth, H.	N.W. Reg.	30.4.50
Delahunty, T. P. J.	L.P. Reg.	3.8.49
Batch, E. B.	H.C. Reg.	28.2.50
Sparrow, V. J.	E.-in-C.O. (Resigned)	31.5.50
Asst. Engr.		
Holt. H. L.	N.W. Reg.	31.3.50
Carrothers, J. K.	N. Ire. Reg.	31.1.50
Hemington, H.	Mid. Reg.	24.4.50
Skea, J.	Scot.	11.4.50
Appleford, L. E.	L.T. Reg.	30.4.50
West, V. A.	N.E. Reg.	30.4.50
Vick, E. H.	N.W. Reg.	29.5.50

Retirements—*continued*

Name	Region	Date
Asst. Engr.—continued		
Rowlands, W.	Mid. Reg. (Health grounds)	17.5.50
Inspector.		
Closney, P. A.	L.T. Reg.	18.3.50
Lee, S. H.	N.W. Reg.	31.3.50
Hastings, A. W.	L.T. Reg.	31.3.50
Maltby, W. A.	L.T. Reg.	25.5.50
Mead, J.	Mid. Reg.	26.5.50
Inspr.—continued		
Eager, J.	H.C. Reg.	19.9.49
Petite, V. D.	H.C. Reg.	6.8.49
Ware, F.	H.C. Reg.	31.7.49
Lewis, H. V.	H.C. Reg.	17.11.49
Rubidge, H. G.	H.C. Reg.	1.12.49
Power, E. M.	H.C. Reg.	19.11.49
Asst. (Scientific).		
Harrison, M. A. (Miss)	E.-in-C.●. (Resigned)	25.5.50

Deaths

Name	Region	Date
Exec. Engr.		
Walton, W. R.	L.T. Reg.	19.5.50
Asst. Engr.		
White, O.	N.W. Reg.	7.3.50
Asst. Engr.—continued		
Webster, G. J.	E.-in-C.●.	26.3.50
Inspector.		
Smart, C.	L.T. Reg.	30.4.50

CLERICAL GRADES

Promotions

Name	Region	Date
S. Ex. Off. to Staff Controller.		
Dunster, H. L.	E.-in-C.●.	1.4.50
H. Ex. Off. to S. Ex. Off.		
Daly, G.	E.-in-C.O.	1.4.50
Ex. Off. to H. Ex. Off.		
Harmon, D. M. (Miss)	E.-in-C.●.	1.4.50
Burrows, W. H.	E.-in-C.●.	1.3.50
Sheppard, A. M. (Miss)	E.-in-C.O.	1.5.50
Ex. Off. to H. Ex. Off.—continued		
Roope, D. M. (Miss)	E.-in-C.●.	29.4.50
Cl. Off. to Ex. Off.		
Rees, I. M. (Miss)	E.-in-C.O.	1.4.50
Curley, J.	E.-in-C.●.	27.2.50
Peacock, C. O. G. G.	E.-in-C.●.	1.3.50
Tucker, F. Y.	E.-in-C.O.	26.4.50
Maskell, S. G.	E.-in-C.●.	1.5.50
Green, B.	E.-in-C.O.	12.5.50
Farr, B.	E.-in-C.O.	9.2.50

Retirements

Name	Region	Date
Staff Controller.		
Ford, F. C.	E.-in-C.O.	31.3.50
H. Ex. Off.		
Child, A. J.	E.-in-C.●.	28.2.50
French, F. S.	E.-in-C.●.	28.2.50
Batey, T. W.	E.-in-C.●.	31.3.50

Transfer

Name	Region	Date
H. Ex. Off.		
Granville, H. G.	E.-in-C.●. to Factories Dept.	20.2.50

DRAUGHTSMEN

Promotions

Name	Region	Date
D'man. Cl. I to Sen. D'man.		
Downes, F. G.	E.-in-C.●.	5.2.50
Waldegrave, R. F.	E.-in-C.●.	5.2.50
●wles, F. H.	H.C. Reg.	15.1.50
D'man. Cl. I to Senr. D'man.—continued		
Todd, J. C. H.	N.W. Reg.	25.1.50
Brown, J. F.	Scot. to W.B.C. Reg.	5.2.50
Howard, G.	Scot.	19.2.50

Transfer

Name	Region	Date
Sen. D'man.		
Ivory, B.	W.B.C. Reg. to N.W. Reg.	5.2.50

JUNIOR SECTION NOTES—

(*continued from page* 113)

many suggestions put forward at the Annual General Meeting indicate another successful programme for our next session.

On 16th February we were honoured with a visit by the President, Mr. H. R. Harbottle, O.B.E., B.Sc., (Eng.), D.F.H., M.I.E.E. Eighty persons attended this meeting, and visitors included members from the Darlington Centre. Mr. Harbottle's paper entitled, "The Main Phenomena of Hearing and their Bearing on the Design of Telephone Communication Systems" was illustrated with slides and was received with great enthusiasm by all present.

On 4th March an interesting visit was made to Smith's Dock Co., Shipbuilding Yard, South Bank. Met by an official, we were shown an array of models of ships constructed by the firm, and had the details of each fully explained. This proved to be of great assistance when going over an actual ship. The Radar equipment had special appeal and was actually seen in operation.

A talk on "Radio Interference Suppression," given by one of our members, Mr. P. L. Hall, on the 16th March, was greatly appreciated—a lively discussion took place.

It is hoped that this support will be maintained.

J. B.

Scarborough Centre

On Thursday evening, 30th March, the final paper for our 1949-50 session was duly presented. It took the form of a Five-Minute Essay Competition, and seven papers were read. The papers ranged from "The Introduction of Auto Switching on the Internal Telegraph Network" to "Basic Principles of Rocket Propulsion," and so close were the markings that the panel of Judges found it very difficult to select the winners.

We are indebted to the Senior Section for their presence and support, particularly to Messrs. Jordan, Sturdy and Murray, who were our Judges. Owing to prior engagements, the Telephone Manager and Area Engineer were unable to be present, and apologies were read on their behalf. Refreshments were served and so ended a most enjoyable evening, and the conclusion of another year's working.

A. B. C.

Sheffield Centre

Thanks to very successful co-operation with the Sheffield Students' Section of the Institution of Electrical Engineers a joint dance was held in January. This was a great success, and all enjoyed the evening. The committee were relieved to find a very small profit showing on the balance sheet, and encouraged by this it is hoped to make the joint dance an annual social event.

The result of a general invitation to the Staff gave us a record attendance one evening in January, when Mr. Clarkstone gave a lecture on, and demonstration of, Television. The company of over 100 included members of the Sheffield Students' Section of the I.E.E. and members of the P.O. Engineering Department from Doncaster. After Mr. Clarkstone had given us a very clear and concise description of what happens in the transmitter and receiver, we sat and watched the results. The only difficulty was in deciding when to close the meeting! However, a fortunate interval in the transmission of a play just gave time to switch off quickly and say "That's all for to-night." We are pleased to record that after the meeting there was an appreciable increase in membership.

T. C. R. H.

BOARD OF EDITORS

H. FAULKNER, C.M.G., B.Sc., M.I.E.E., Chairman.
F. E. NANCARROW, O.B.E., A.R.C.Sc., M.I.E.E.
P. B. FROST, B.Sc., M.I.E.E.
A. H. MUMFORD, O.B.E., B.Sc.(ENG.), M.I.E.E.
W. T. GEMMELL, A.C.G.I., B.Sc., M.I.MECH.E., A.M.I.E.E.
W. WEST, B.A., M.I.E.E.
D. A. BARRON, M.Sc., A.M.I.E.E.
A. F. STOLLARD.
G. E. STYLES, A.M.I.E.E., Managing Editor.
W. A. HUMPHRIES, A.M.I.E.E.
J. P. HARDING, B.Sc.(ENG.), A.M.INST.C.E., A.M.I.E.E. } Assistant Editors.
A. J. HUTCHISON, Secretary-Treasurer.

Copyright

The entire contents of this JOURNAL are covered by general copyright, and special permission is necessary for reprinting long extracts, but Editors are welcome to use not more than one-third of any article, provided credit is given at the beginning or end thus: "From the *Post Office Electrical Engineers' Journal*."

The Board of Editors is not responsible for the statements made or the opinions expressed in any of the articles in this JOURNAL, unless such statement is made specifically by the Board.

Communications

All communications should be addressed to the Managing Editor, *P.O.E.E. Journal*, Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Telephone: HEAdquarters 1234. Remittances should be made payable to "*The P.O.E.E. Journal*" and should be crossed " & Co."

Binding Cases

Cases for binding are available, and may be obtained from the Local Agents for 2s. Subscribers can have their copies of Volumes bound, at a cost of 7s. 6d., by sending the complete set of parts to the Local Agents or to the *P.O.E.E. Journal*, Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Orders for binding for Vols. 1-19 should indicate whether the original binding case with black lettering, or the later pattern with gold, is required. Cases with gold lettering are the only type stocked from Vol. 20 onwards.

Back Numbers

The price of the JOURNAL, which is published quarterly, is 1s. 6d. (1s. 9d. post free) per copy, or 7s. per annum post free. Back numbers can be supplied, subject to availability of stocks, at 1s. 6d. each (1s. 9d. post free). Orders for back numbers may be sent to the Local Agents or to the Publishers.

Advertisements

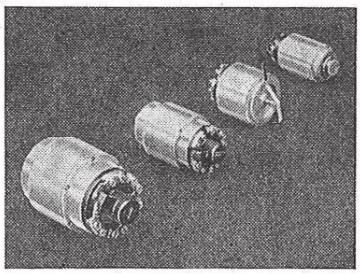
All communications relating to space reservations should be addressed to the Advertisement Editor, *P.O.E.E. Journal*, Alder House, Aldersgate Street, London, E.C.1. Communications regarding advertisement copy, proofs, etc., should be addressed to the Publishers, Messrs. Birch & Whittington (Prop. Dorling & Co. [Epsom], Ltd.), 49 Upper High Street, Epsom, Surrey.

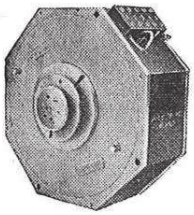
INDEX TO ADVERTISERS

	Page
Alton Battery Co., Ltd., The	vi
Automatic Coil Winder & Electrical Equipment Co., Ltd.	xiii
Automatic Telephone & Electric Co., Ltd.	x, xi
Bennett College, The	ii
British Electric Resistance Co., Ltd.	ii
British Institute of Engineering Technology	vii
Creed & Co., Ltd.	xii
Ericsson Telephones, Ltd.	xv
Evershed & Vignoles, Ltd.	v
General Electric Co., Ltd., The	xvi, xvii
Great Northern Telegraph Co., Ltd., The	xviii
Hall Telephone Accessories, Ltd.	ix
International Correspondence Schools, Ltd.	xix
Macdonald & Co. (Publishers) Ltd.	xix
Muirhead & Co., Ltd.	iii
Neill, James, & Co., Ltd.	vii
Painton	xx
Pirelli-General Cable Works, Ltd.	xx
Pitman, Sir Isaac, & Sons, Ltd.	xix
Savage Transformers, Ltd.	ii
Savage, W. Bryan, Ltd.	xviii
Siemens Brothers & Co., Ltd.	viii
Smith, Frederick, & Co.	ii
Standard Telephones & Cables, Ltd.	xiv
Sullivan, H. W., Ltd.	ix
Telephone Manufacturing Co., Ltd.	xiii
Tungstone Products, Ltd.	iv
Westinghouse Brake & Signal Co., Ltd.	vii
Winn & Coales, Ltd.	xix

REMOTE POSITION INDICATION SERVO CONTROL COMPUTATION

MAGSLIPS
SIZES: 1½", 2" and 3"
VOLTAGES: 50V to 150V according to type
FREQUENCIES: 50c/s to 1100c/s according to type





INDUCTIVE POTENTIOMETER
(IPOT)
DIMENSIONS: 6½" x 6½" x 3 11/16"
SUPPLY: 50V 50c/s

POST THIS COUPON FOR DESCRIPTIVE LITERATURE

MUIRHEAD & CO., LTD.
BECKENHAM · KENT · ENGLAND

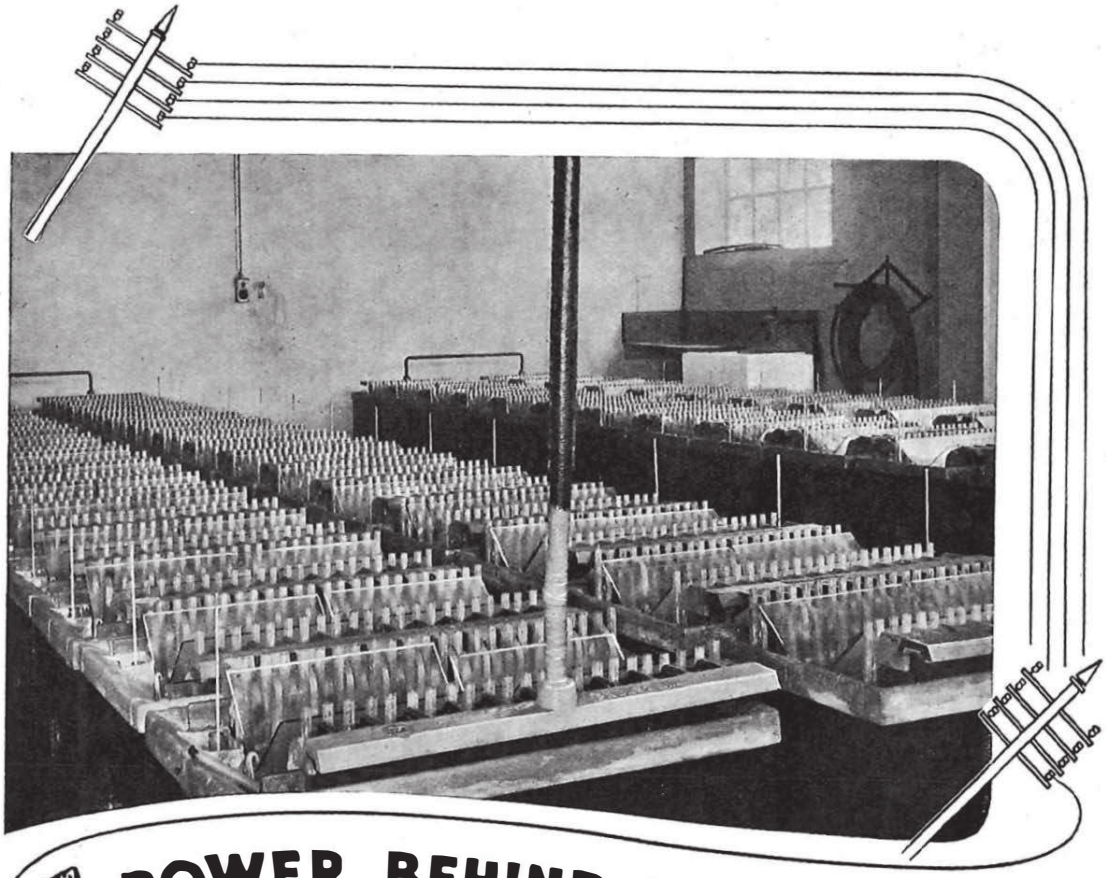
Please send me Bulletins B-580 and B-604 fully describing the Magslips and Ipots advertised in the "Post Office Electrical Engineers' Journal"

NAME_____
ADDRESS_____

MUIRHEAD & CO., LTD.
PRECISION ELECTRICAL INSTRUMENT MAKERS
BECKENHAM·KENT·ENGLAND
Phone: BECkenham 0041 Telegrams & Cables: MUIRHEADS ELMERS-END

PRECISION MUIRHEAD ELECTRICAL INSTRUMENTS

284



POWER BEHIND THE LINES

TUNGSTONE PLANTÉ CELLS are being supplied to the British Post Office and Post and Telegraph Departments in many countries overseas. They conform fully to G.P.O. and British Standard specifications.

OPEN TYPE CELLS

Similar to the illustration above, these are available in glass and/or lead lined wooden boxes in capacities from 100 a.h. to 500 a.h.

ENCLOSED TYPE CELLS

As illustrated on the right, these are in moulded glass boxes with sealed-in lids. Capacity range from 10 a.h. to 200 a.h.

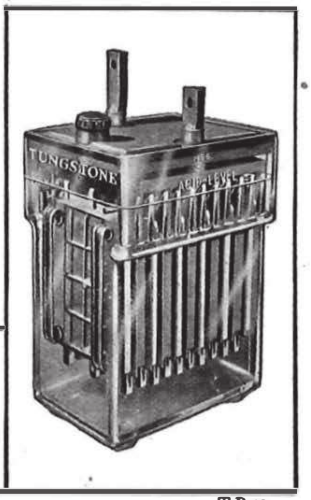
REPLATALS

We are in a position to supply plates for the replating of any existing Planté Battery.

HIGH VOLTAGE TELEPHONE BATTERIES

Portable Type. Standard layout for 50 volts, in waxed hard wood crates, exactly to the requirements of the G.P.O.

Overseas customers are invited to cable or write their enquiries for batteries or parts. Visitors to London are welcome at our offices.



TUNGSTONE *Batteries*

For further particulars write : **TUNGSTONE PRODUCTS LIMITED**

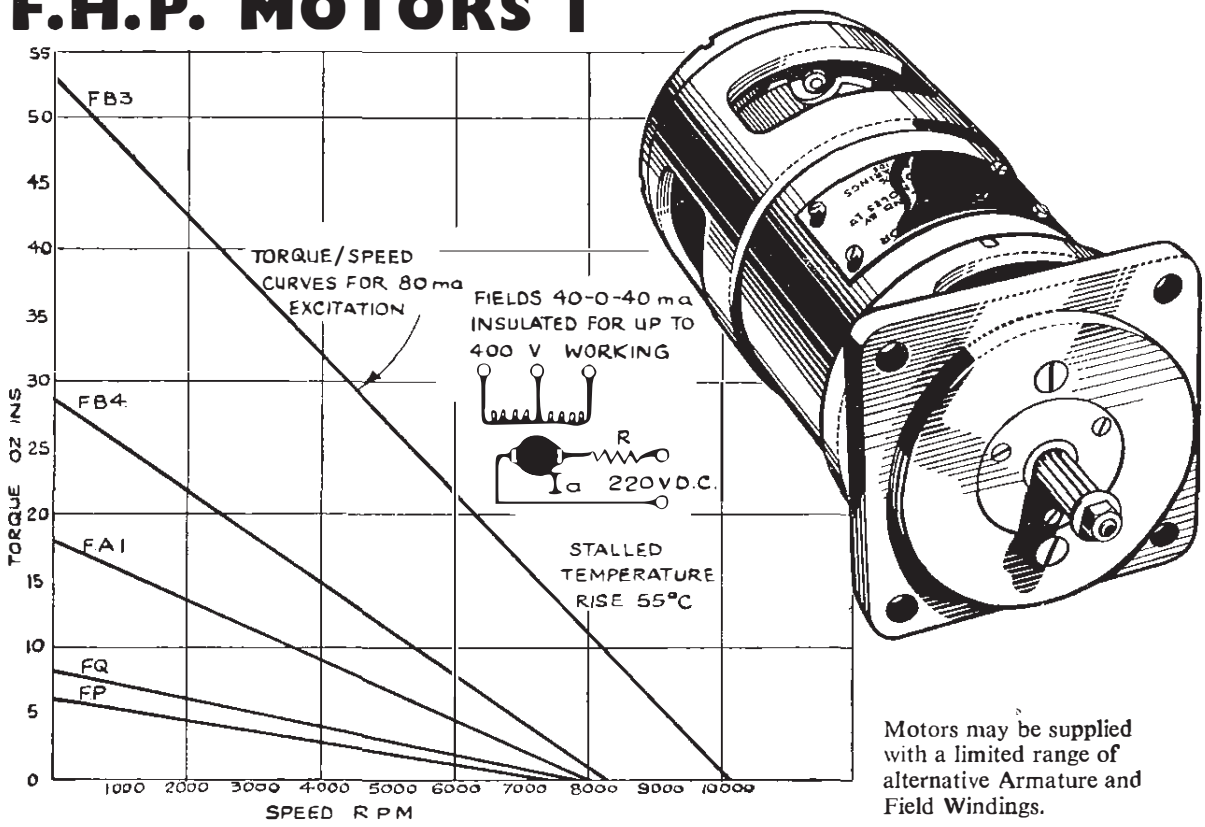
10 SALISBURY SQUARE · LONDON · E.C.4 · ENGLAND. Cables: "Dilutum" London.

T.B.12

DATA SHEET No. 1

EVERSHED
SPECIAL DUTY F.H.P. MOTORS

TYPICAL D.C. SERVO MOTORS FOR ELECTRONIC CONTROL



Motors may be supplied with a limited range of alternative Armature and Field Windings.

F.B.3 and F.B.4 Motors, fitted with Integral Field Surge Suppressors.

Shafts Plain or D.P. Spline.

All Motors rated for a stalled temperature rise of 55°C.

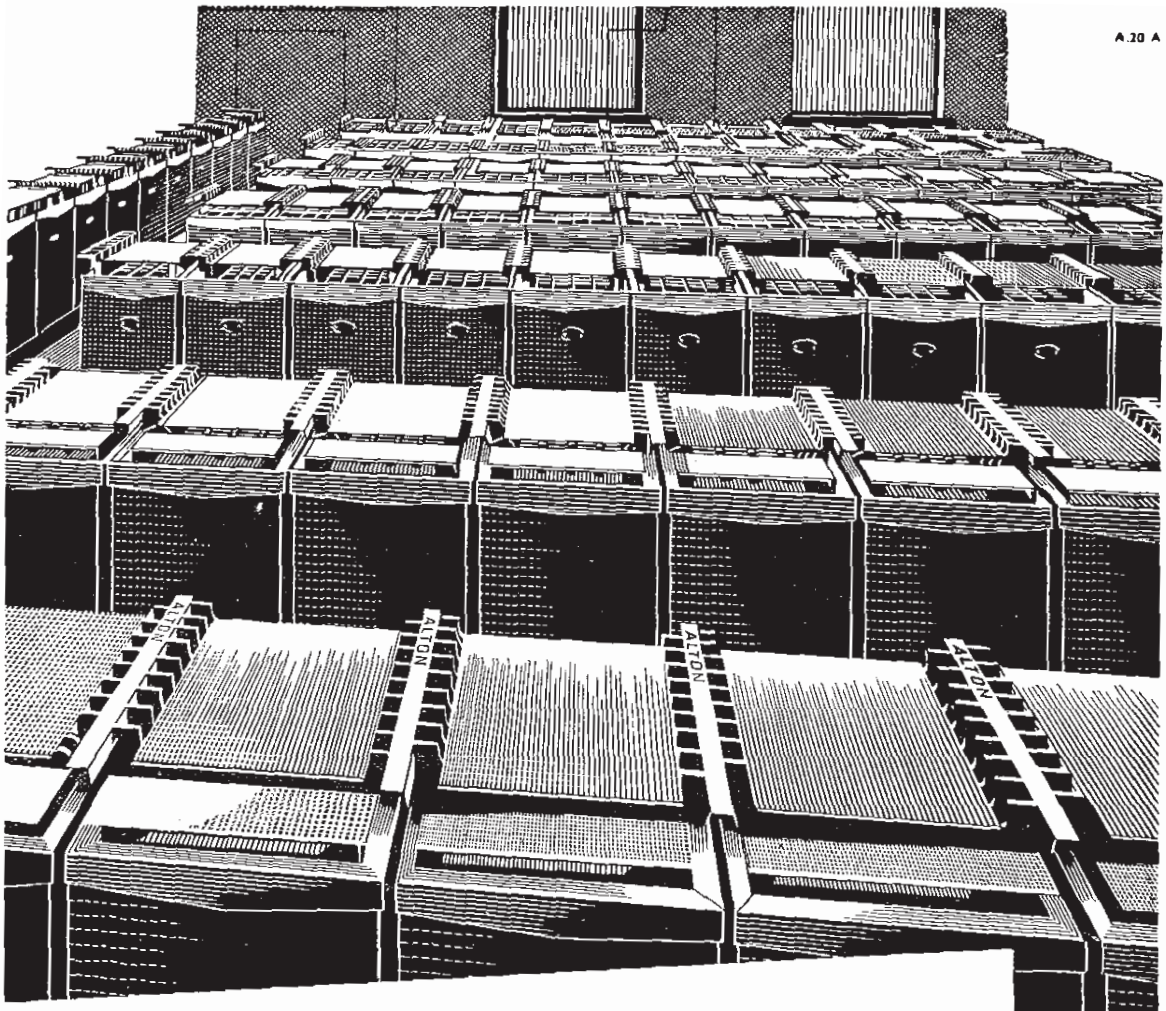
Send for the Evershed Small Motors' Data Book, X22.

FRAME SIZE	MOMENT OF INERTIA OZ. INS²	BRUSH & BEARING FRICTION OZ. INS.	Ia AMPS
F.P.	0.5	0.5	0.25
F.Q.	0.75	0.5	0.33
F.A.1	1.8	0.5	0.75
F.B.4	2.2	1.0	1.5
F.B.3	2.2	1.0	3.0

EVERSHED AND VIGNOLES LIMITED

ACTON LANE WORKS · CHISWICK · LONDON · W4

Telephone: Chiswick 3670 *Telegrams: Megger, Chisk, London* *Cables: Megger, London*



Alton has been exporting batteries for thirty years. In installations in sixty-five countries Alton Batteries, in capacities from 10 to 15,000 ampere-hours, are giving the service only good batteries can give. Alton, in any language, means good batteries and firm delivery dates.

ALTON

BATTERIES OF MERIT

THE ALTON BATTERY COMPANY LIMITED
Alton, Hants. Telephone: Alton 2267 and 2268
Telegrams: Battery, Alton

Alton can also supply renewal plates for all makes of battery, British & Continental

VALUABLE FREE BOOK

Tells You How to Pass Your C. & G. or Promotion Exam. at *First* Attempt!

All Post Office Engineering personnel who are anxious to obtain early promotion should at once send for a copy of our handbook "**ENGINEERING OPPORTUNITIES**," which, among other intensely interesting matter, describes our unique methods of preparation for **TECHNICAL APPOINTMENTS IN THE POST OFFICE** (Assistant Engineer—New Style and Assistant Traffic Superintendent), **CITY AND GUILDS EXAMINATIONS** in Principles of Telecommunications (1-5), Radio (1-4), Telephone Exchange Systems (1-3), Telegraphy (1 and 2), Line Transmission (1 and 2), Lines Plant Practice (1 and 2), Mathematics for Telecommunications (1-5), Electrical Engineering Practice (Prelim. Inter. and Final), and outlines a wide range of non-examination courses in all branches of Electrical, Mechanical, Civil, Automobile, Aeronautical and Radio Engineering.

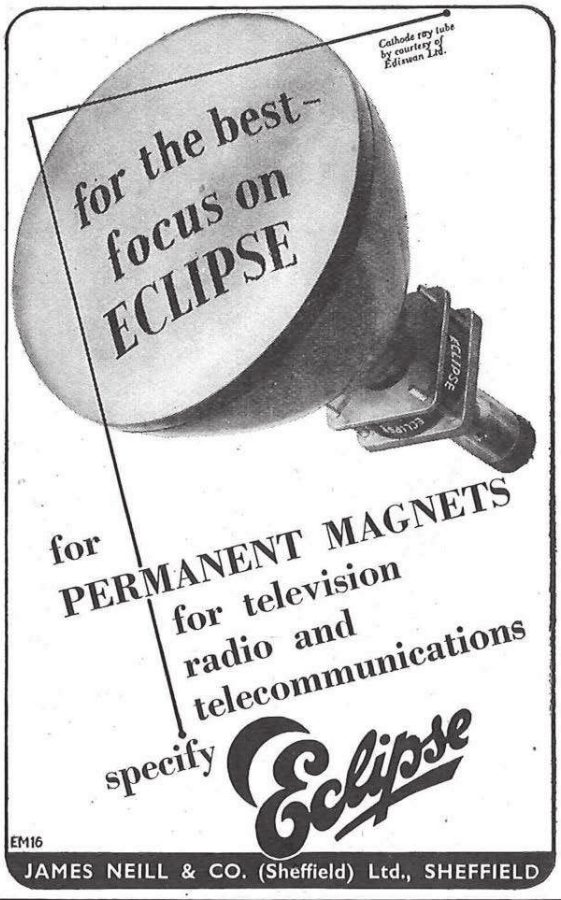
Assistant Engineer and Assistant Traffic Superintendent. Open competitions now resumed. Age extensions for established Civil Servants. Ask us for full details

We definitely guarantee "NO PASS—NO FEE"

If you intend to make the most of to-day's opportunities, you cannot afford to miss reading "**ENGINEERING OPPORTUNITIES.**" It tells you everything you want to know to secure advancement, and describes many opportunities you may now be missing through lack of information. Send for your copy to-day—**FREE** and without obligation.

BRITISH INSTITUTE OF ENGINEERING TECHNOLOGY
369 SHAKESPEARE HOUSE, 17-19 STRATFORD PLACE, LONDON, W.1

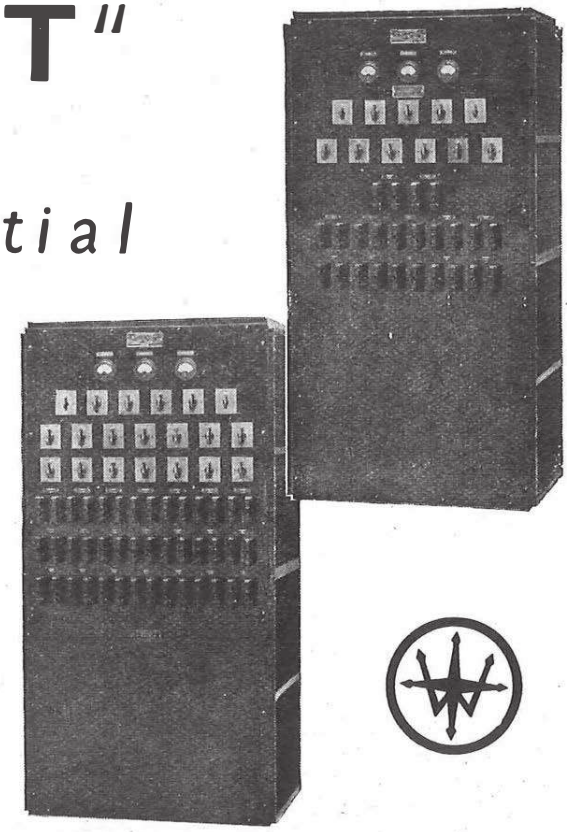
BIET



The "WESTAT"

system of constant potential rectification

is extensively used for battery charging, and can be designed as a charger with a high degree of taper, or as a cyclic charger, with the great advantage that it is practically independent of mains fluctuations.

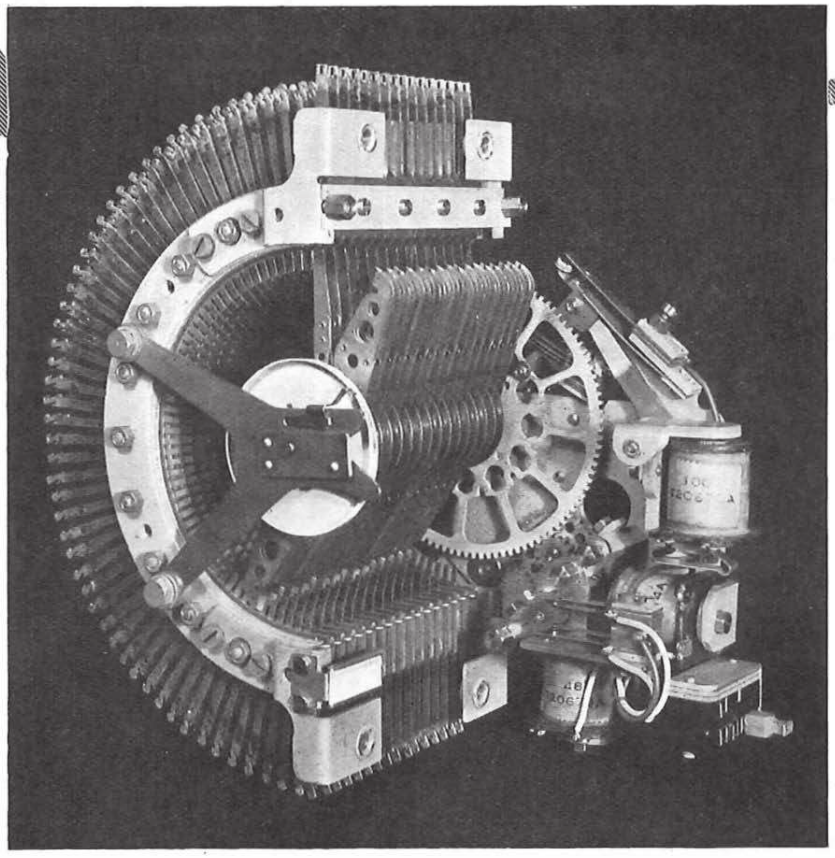


WESTINGHOUSE
WESTALITE
RECTIFIERS

Write for Data Sheet No. 62 to Dept. P.O.E.E.J. 3

WESTINGHOUSE BRAKE & SIGNAL CO., LTD.
82 York Way, King's Cross, London, N.1

SIEMENS *High-Speed* MOTOR UNISELECTOR



For their Trunk Mechanization Scheme the British Post Office has adopted the High-Speed Motor Uniselector illustrated above.

This Automatic switch has a searching speed of 200 outlets per second. This high speed together with its thorough reliability in operation render it the ideal switch for automatic trunk working.

The original type of Motor Uniselector has been in use for Line Finders at North Exchange, London, since June 1935

SIEMENS BROTHERS & CO., LIMITED
WOOLWICH • LONDON • S.E.18.

MICRO-HARDNESS TESTER

DEVELOPED BY THE GUEST, KEEN, NETTLEFOLD LABORATORIES

This new instrument is suitable for use with a standard metallurgical bench type microscope.

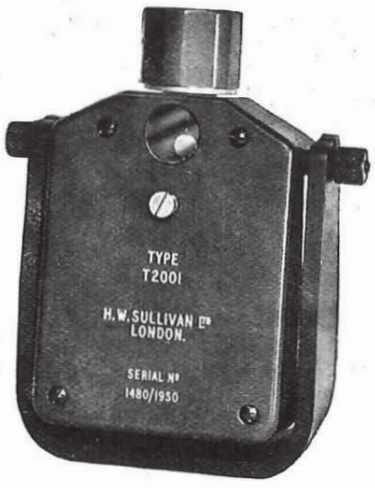
It is designed to give a range of loads from 1 to 100 grams with a high degree of accuracy. The associated mechanical stage is provided with micrometer adjustments which permit very accurate movement of the specimen which is necessary for some Micro-hardness investigations. Some applications of this instrument are the measurements of :—

- ★ Hardness of phases of a micro structure.
- ★ Hardness of plated surfaces.
- ★ Case hardening and nitriding.
- ★ Hardness of thin wires, foils and soft metals.
- ★ Hardness variation in cold worked specimens.

Descriptive folder, operating instructions, prices and specialised technical details from sole manufacturers :

AN H.T.A. PRODUCT

HALL TELEPHONE ACCESSORIES LTD.
Precision Engineers and Instrument Makers
70 DUDDEN HILL LANE, LONDON, N.W.10.
Tel.: Willesden 5141 (8 lines). 'Grams: Halltelacc, Harles, London.



We shall be pleased to select for any prospective purchaser a galvanometer suited to any particular industrial application or measurement problem.

A NEW SULLIVAN SUSPENDED COIL PORTABLE GALVANOMETER UNIT

. . . which may be supplied alone or boxed complete with scale, illumination (with mains transformer) and novel scale magnification.

The unit is exceptionally well constructed and reliable in performance and is **completely enclosed within a draught and dust-tight bakelite case** measuring only 8 cm. by 4 cm. by 12 cm. high. When boxed as a complete measuring system it measures only 26 cm. by 17 cm. by 15 cm.

A complete series of these portable galvanometer units is available, mounted or unmounted, with many scale arrangements and **for any Sensitivity, time period or resistance.**

H. W. SULLIVAN
LIMITED

LONDON, S.E.15

Telephone : New Cross 3225 (P.B.X.)

PRODUCTS OF THE COMPANY INCLUDE: DIRECTOR AND NON-DIRECTOR AUTOMATIC TELEPHONE EXCHANGE EQUIPMENT, AUTOMATIC TRUNK EXCHANGES, RURAL AUTOMATIC EXCHANGES, PRIVATE AUTOMATIC EXCHANGES, PRIVATE AUTOMATIC BRANCH EXCHANGES, SINGLE AND MULTI-CHANNEL (CARRIER) TRANSMISSION EQUIPMENT; INTERCOM KEY-CONTROLLED TELEPHONE EQUIPMENT, CENTRALISED SUPERVISORY REMOTE INDICATION AND CONTROL EQUIPMENT; "RYTHMATIC" RIPPLE CONTROL EQUIPMENT; "ELECTRO-MATIC" VEHICLE-ACTUATED TRAFFIC SIGNALS; MINE TELEPHONES AND COLLIERY SIGNALLING EQUIPMENT.

A stage in the production of crystals used to control frequency stabilisation in carrier oscillators. The crystal, held in a jig, is being fitted with phosphor-bronze wires .008 in. diameter which are soldered to both sides of the prepared crystal simultaneously by means of two hot air jets.

From First Principles to Finished Product

The behaviour of quartz crystal under physical and electrical stress—piezo electricity—was discovered by Pierre and Jacques Curie as long ago as 1881. Since then this phenomenon has been the subject of intensive research. Engineers of A.T.M. organisation have applied it frequently in the solution of problems in the field of telecommunications. One application which involves the production of the quartz plates to exceptionally fine limits is the stabilisation of carrier frequencies in A.T.M. multi-channel carrier systems.

ATM
REGD. TRADE MARK

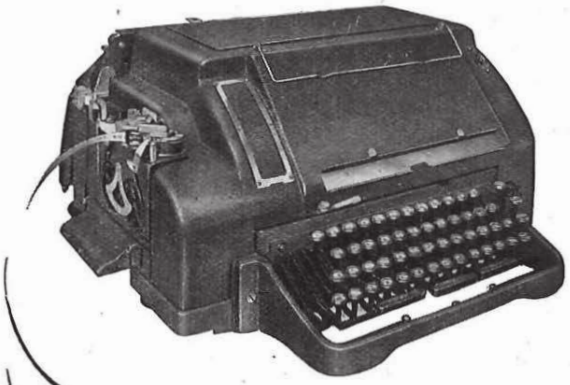
AUTOMATIC TELEPHONE & ELECTRIC CO. LTD.

Export Department: Strowger House, Arundel Street, London, W.C.2. Telephone: TEMple Bar 9262.

Cablegrams: Strowgerex, London. Strowger Works, Liverpool, England.

Creed
TELEPRINTERS

Built by specialists in machine telegraphy~



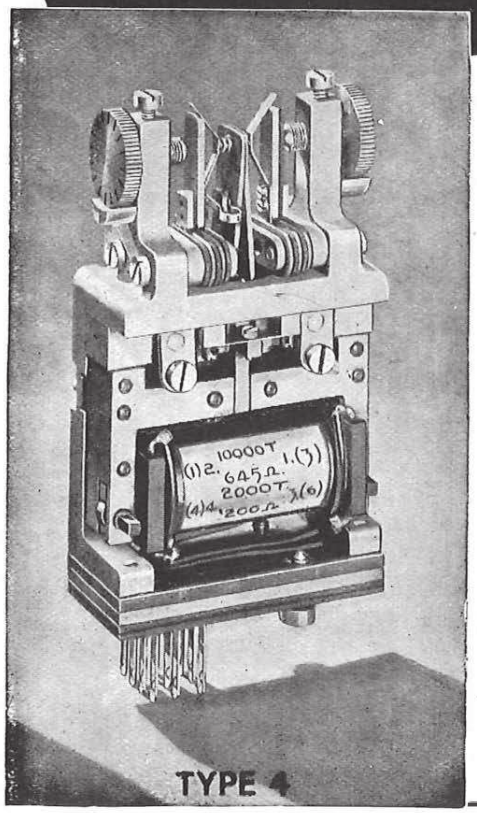
N°47 TAPE MODEL

Write for Bulletin N° 21

Creed & Company Limited

TELEGRAPH HOUSE
CROYDON, ENGLAND

CARPENTER Polarized RELAY
TYPE 4



This is a medium speed, sensitive relay with long contact travel designed primarily as a telephone impulsing relay (D.C. dialling up to 100 miles and V.F. dialling on trunk circuits). It has also been successfully adopted for use in Telex systems.

Its sensitivity is such that when the gap is adjusted to .004 in. the relay will just operate at 50 cycles with 4 ampere-turns (corresponding to approximately 1 mVA) or on $2\frac{1}{2}$ D.C. ampere-turns at low speeds. In service, however, the relay is normally operated at currents substantially larger than the minimum operating current.

Contact chatter is absent if the contact gap does not exceed .004 in. The contact gap is adjustable by means of fine pitch screws with knurled heads marked with .001 in. divisions.

Contacts on the armature tongue are insulated from it and thereby from the frame.

Terminals for soldered connections are fitted as standard.

The relay is supplied with a magnetic screening cover with transparent removable top to facilitate contact adjustment.

Dimensionally the relay is interchangeable with the type "3000" relay and can be supplied to fit directly to the drilling normally provided for the "3000" relay.

Dimensions of the Type 4 Carpenter Relay are :—(With cover. Excluding wiring tags) $3\frac{9}{16}$ ins. high × $2\frac{3}{16}$ ins. wide × 1 in. deep. Weight : 13 ozs.

Complete details available on request. *Manufactured by the Sole Licensees :—*

TELEPHONE MANUFACTURING CO. LTD.

Contractors to the British Commonwealth and Foreign Governments

HOLLINGSWORTH WORKS DULWICH LONDON, S.E.21

Telephone : GIPsy Hill 2211 (10 lines)

The AvoMeter is one of a useful range of "Avo" electrical testing instruments which are maintaining the "Avo" reputation for an unexcelled standard of accuracy and dependability—in fact, a standard by which other instruments are judged.

ONE INSTRUMENT

measures :—

Current, A.C. and D.C. (0 to 10 amps.)
Voltage, A.C. and D.C. (0 to 1,000 v.)
Resistance (up to 40 megohms)
Capacity (·01 to 20 mfds.)
Audio-frequency Power Output (0 to 2 watts)
Decibels (− 25 Db. to + 16 Db.)

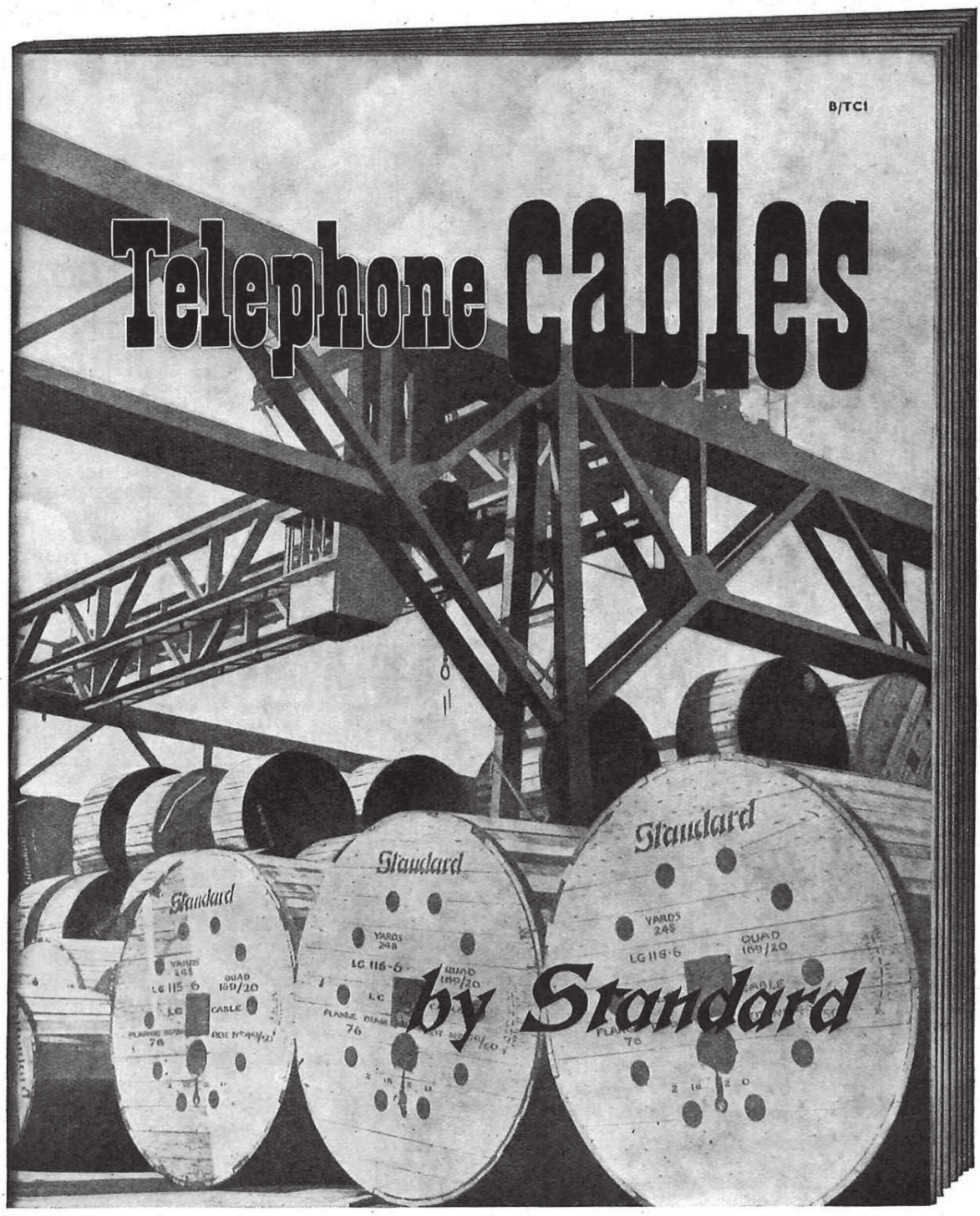
Write for fully descriptive pamphlet.

'AVO'
Meters that Matter

THE Model 7 Universal AvoMeter is the world's most widely used combination electrical measuring instrument. It provides 50 ranges of readings on a 5-inch hand-calibrated scale, and is guaranteed accurate to B.S. first grade limits on D.C. and A.C. from 25 c/s to 2 kc/s. It is self-contained, compact and portable, simple to operate and almost impossible to damage electrically. It is protected by an automatic cut-out against damage through severe overload.

Sole Proprietors and Manufacturers :—

THE AUTOMATIC COIL WINDER & ELECTRICAL EQUIPMENT Co. Ltd.
Winder House, Douglas Street, London, S.W.1. *Phone : VICtoria* 3404-9



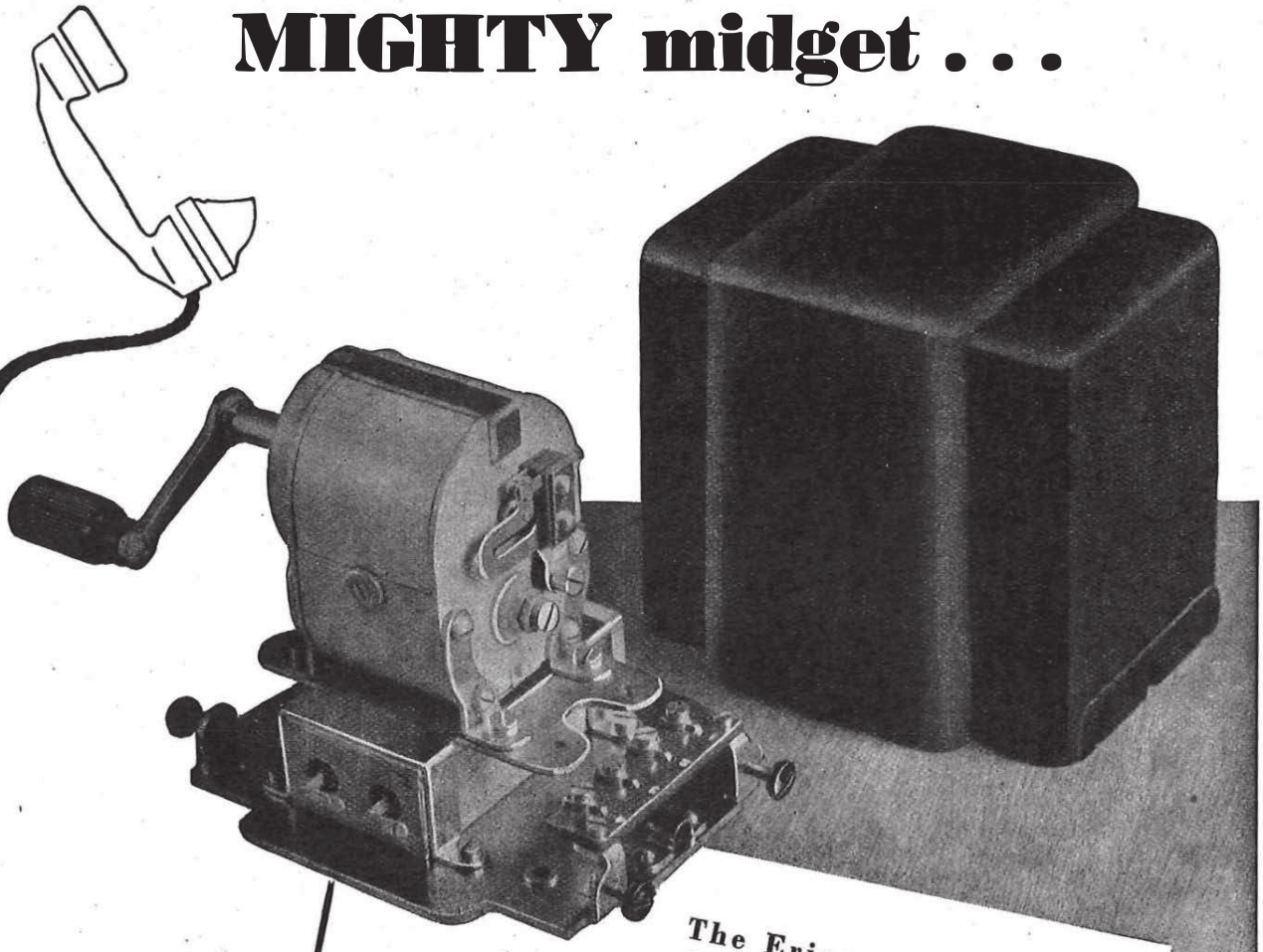
THIS catalogue, No. B/TC 1, contains the latest information on a wide range of telecommunication cables manufactured by "STANDARD."

Standard Telephones and Cables Limited

(Registered Office: Connaught House, Aldwych, London, W.C.2)

TELEPHONE LINE DIVISION. NORTH WOOLWICH, LONDON, E.16

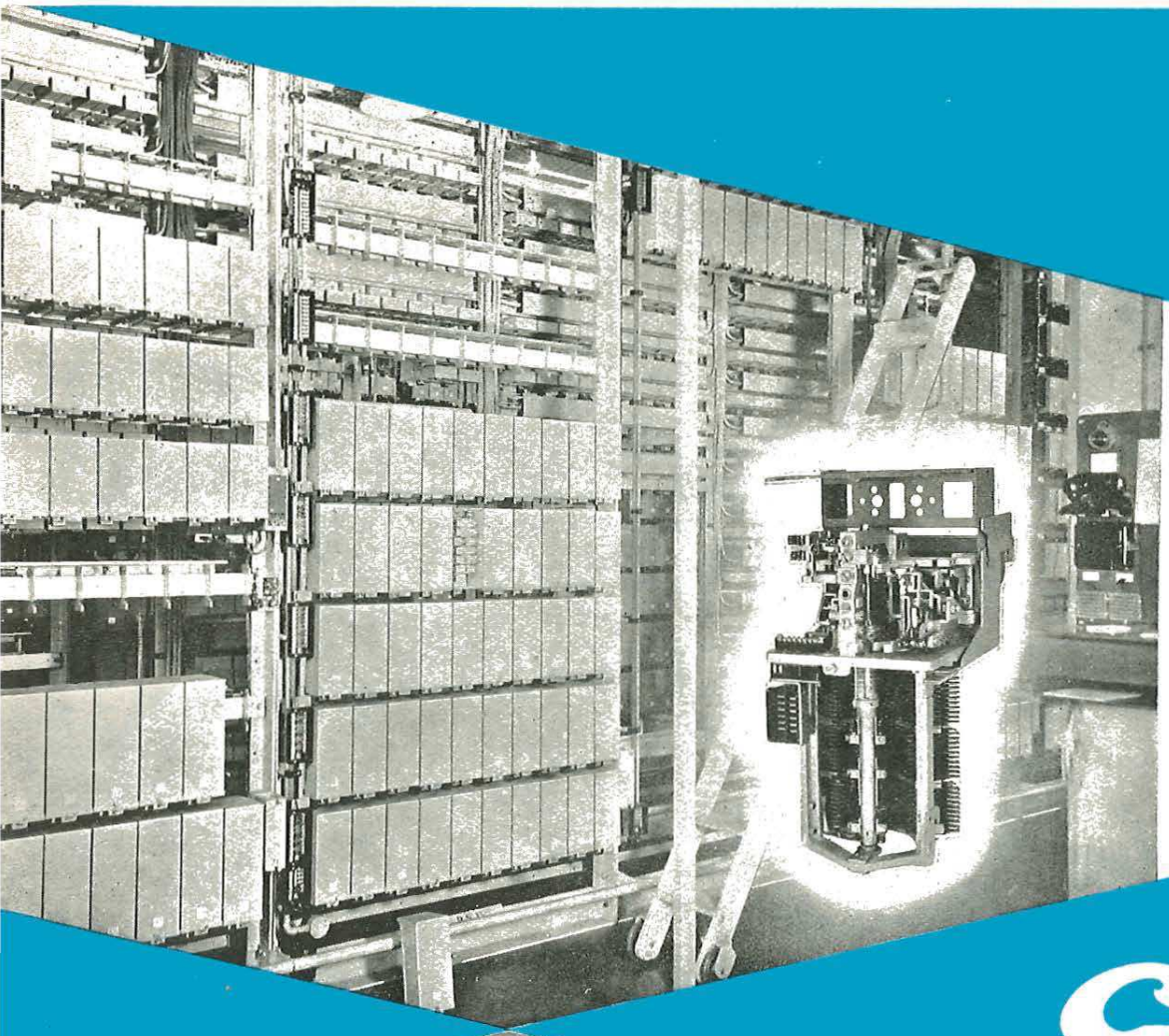
MIGHTY midget . . .



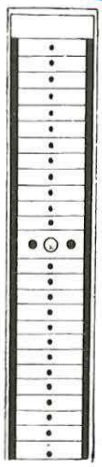
The Ericsson **ALNICO GENERATOR** illustrated is a robust yet elegant example of Ericsson practice. Has an output equivalent to the old 4-Bar unit but is less than half its size and weight. Certified safe for use in mines, and can be supplied unmounted or without the moulded bakelite case. Our heavy duty **ALNICO** generator is slightly larger but uses the same case.

THE Ericsson ALNICO GENERATOR

ERICSSON TELEPHONES LTD. · *Head Office:* 22 LINCOLN'S INN FIELDS, LONDON, W.C.2. · *Tel:* HOL. 6936
Works: BEESTON, NOTTS.



G.E.C.



LINE AND RADIO SYSTEMS

TELEPHONE EXCHANGES & INSTRUMENTS

MAJOR PRODUCTS

Automatic and manual exchanges of any capacity.

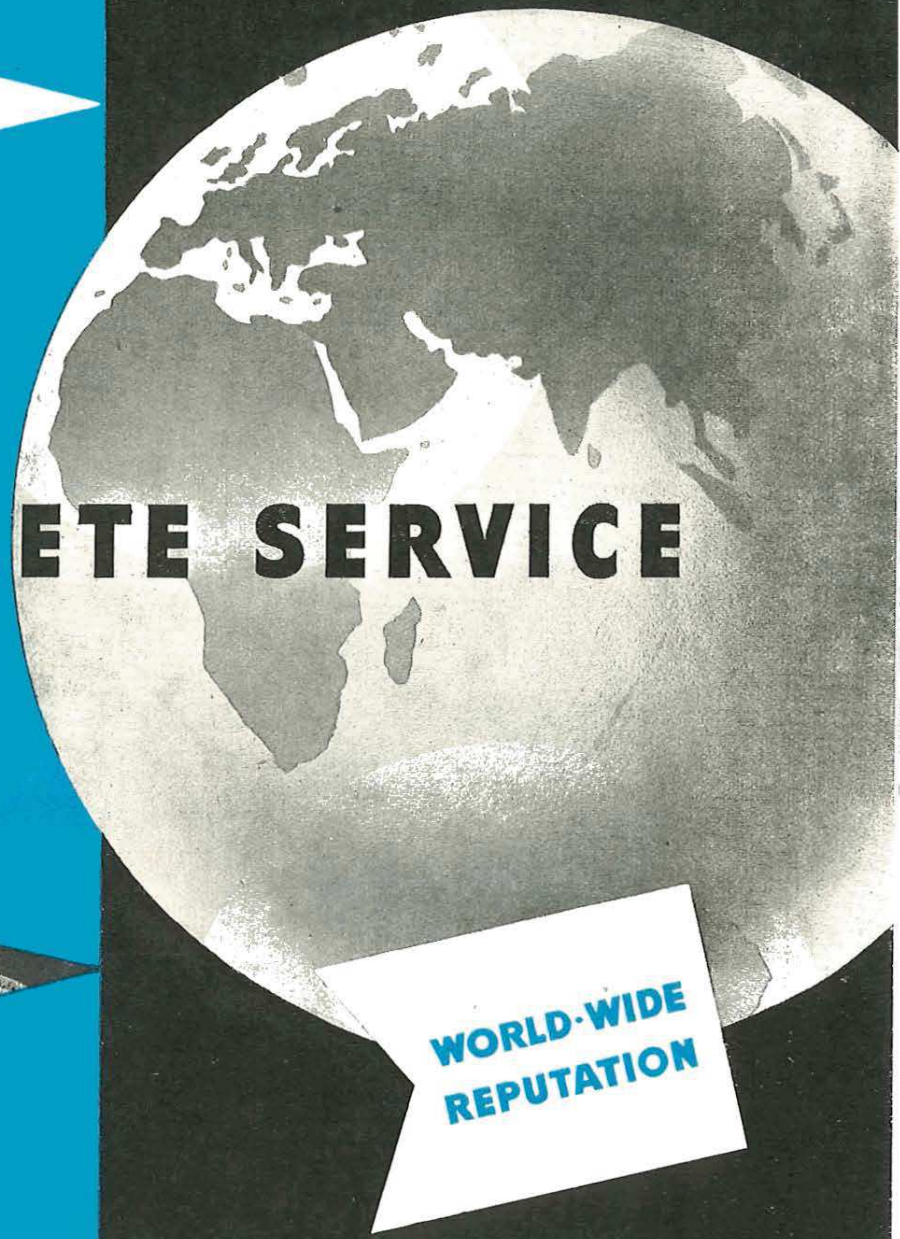
Telephone transmission systems for coaxial tubes, underground cables, open-wire lines and radio links.

H.F., V.H.F., and U.H.F. radio systems, (including wide-band television links).

Telephone instruments for all purposes.

Cables and testing equipment, (by associated Companies).

Special systems for the control of electric power distribution networks, railways, water undertakings, etc.



THE COMPLETE SERVICE

WORLD-WIDE REPUTATION

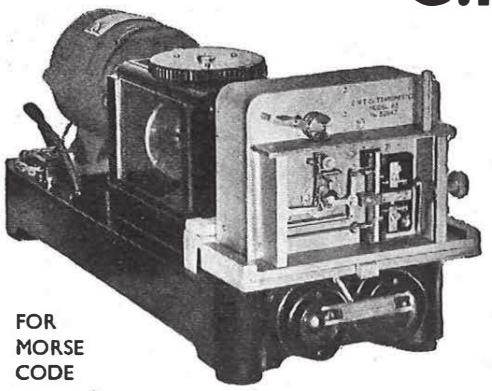
THE GENERAL ELECTRIC COMPANY LIMITED OF ENGLAND

TELEPHONE, RADIO & TELEVISION WORKS, COVENTRY, ENGLAND. Phones Coventry 4111 (10 lines) Telegrams and Cables: "Springjack Coventry."

HEAD OFFICE: MAGNET HOUSE, KINGSWAY, LONDON, W.C.2. Phone: Temple Bar 8000 (90 lines). "Electricity, Westcent, London." Cables "Polyphase, London."

UNIVERSALLY ADOPTED

G.N.T.Co. TRANSMITTER MODEL 112



FOR MORSE CODE

13-250 words per minute without gear changes or readjustments.

Absolutely constant speed at all settings notwithstanding large voltage variations.

Noted for its easy maintenance.

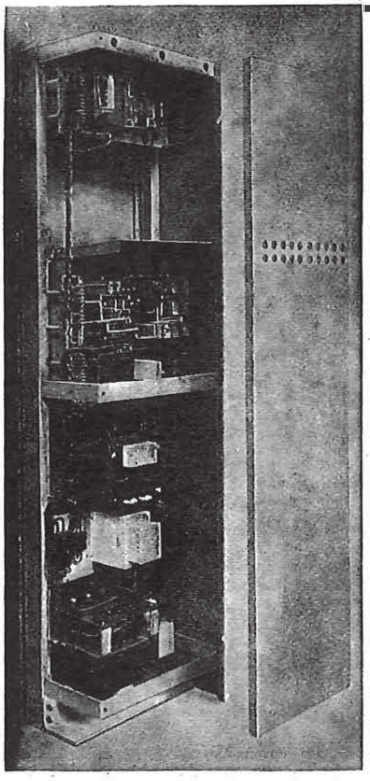
Supplied with A.C. or D.C. motors as required.

THE GREAT NORTHERN TELEGRAPH CO. LTD.
OF DENMARK

KONGENS NYTORV 28
COPENHAGEN K. - DENMARK

AND

5, ST. HELEN'S PLACE,
LONDON, E.C.3



The Mark II series of

SAVAGE AMPLIFIERS

for Broadcast Relay

● These Amplifiers are examples of what careful design can achieve. A lift-off back panel affords immediate access for maintenance purposes and the removal of six screws releases the side covers of the rack and exposes all the interpanel wiring. Even when the rack is sandwiched between others the side covers can be removed just as easily.

All valves are accessible from the front of the rack, and are protected by quick release grilles. The rack is completely flat fronted. The general appearance is further enhanced by the absence of a projecting front foot, and the masking of all panel fixing bolts. Similar racks carrying auxiliary apparatus can be placed side by side with amplifiers so that the whole installation is uniform in appearance.

Complete specifications available on request.

WESTMORELAND ROAD
LONDON N.W.9
TELEPHONE: COLINDALE 7131

W. BRYAN SAVAGE LIMITED

Denso

Regd. Products

has your Corrosion Problems TAPED

Denso Tape protects mains, services and all metalwork, below or above ground, against the menace of chemical and electrolytical corrosion. Ideal for water- and gas-proofing and an aid to frost-proofing. Emergency repairs to gas mains and services. Water-proofing temporary cable openings.
Specifications and Price Lists of "Denso" Anti-corrosive and Sealing Products without obligation from :—

WINN & COALES LTD.

TERMINAL HOUSE, GROSVENOR GARDENS, LONDON, S.W.1
Telephone : SLOane 6146/7. *Telegrams : DENSELTE, SOWEST, LONDON*

SOUND INSTRUCTION by Postal Method

The I.C.S., largest school in the world devoted to spare-time training by the postal method, offers you highly specialised Courses for the following examinations:

P.M.G. Certificates for Wireless Operators.
C. & G. Illumination Engineering (Inter.)
C. & G. Electrical Engineering Practice, Installation and Telecommunications.
Graduateship of the B.I.R.E.

I.C.S. Examination students are coached till successful.

Other Courses meet the requirements of all who desire to qualify for responsible positions in Electric Power, Illumination, Heating and Traction Systems. Equally successful is our instruction for Telegraph and Radio Engineers, Radio Servicemen, and in Elementary Radar and Electronics, Advanced Short-Wave Radio and Television Technology.

Instruction is by correspondence from textbooks specially prepared by many experts.

WRITE FOR OUR SPECIAL BOOKLET and state the particular subject or Examination in which you are interested.

YOU MAY USE THIS COUPON

International Correspondence Schools Ltd.
Dept. 108, International Buildings, Kingsway, London, W.C.2

Please send me, free of charge, your special booklet on.....

Name..... *Age*.....
(BLOCK LETTERS, PLEASE)

Address .....

.....

I.C.S.

THE THEORY AND DESIGN OF INDUCTANCE COILS

By V. G. WELSBY, Ph.D., A.M.I.E.E.,
Post Office Research Station

This book is intended to assist the circuit designer in selecting the coil design most suitable for a given purpose, and to enable him to predict the changes which must be made in a given design in order to obtain any desired performance of the resulting coil. It will also appeal to students who must obtain a clear understanding of the applications and design of inductance coils.

60 *illustrations* 18/- net

MACDONALD & CO.
(Publishers) LTD.
43, LUDGATE HILL, LONDON, E.C.4

PITMAN BOOKS

Antenna Theory and Design
(2 Vols.)

By H. Paul Williams, Ph.D., A.M.I.E.E., Sen.M.I.R.E. Profusely illustrated. Vol. I (Foundations of Antenna Theory) 21/- net. Vol. II (The Electrical Design of Antennæ) 63/- net. Just published.

Electric Cables

By Francis W. Main, M.I.E.E. A practical guide to the properties, construction, installation and maintenance of electric cables, with information on super-tension cables and other modern developments. 52 illustrations. Third Edition. 12/6 net.

Power System Interconnection

By H. Rissik. An important work, invaluable for the practising electrical engineer and a reliable textbook for the advanced student. Second Edition. 25/- net.

Telephony—Vol. I

By J. Atkinson, A.M.I.E.E. The first volume of a completely revised edition of Herbert and Procter's great work, recognized as the standard guide to telephony. This volume deals with general principles and manual exchange systems. 694 illustrations. 35/- net.

PITMAN, *Parker Street, Kingsway, London, W.C.2*

TELEPHONE CABLES

OUR BROCHURE No. 9E (1949), GIVING INFORMATION AND SPECIFICATIONS FOR A WIDE RANGE OF TELECOMMUNICATION CABLES MANUFACTURED BY US, IS AVAILABLE UPON REQUEST.

TELEPHONE: SOUTHAMPTON 2141 (5 lines).

PIRELLI-GENERAL
CABLE WORKS, Ltd., SOUTHAMPTON.

TELEGRAMS "PIGEKAYBEL SOUTHAMPTON

MINIATURE VITREOUS ENAMELLED RESISTOR

TYPE M.V.1

RATING 3 watts for 250°C. rise.

RESISTANCE RANGE - 1-4700 ohms.

Full rated watts over the whole resistance range.

DIMENSIONS - 15/32" × 13/64".

Agents in Switzerlsed : Arnold Kleiner, Zug

TYPE APPROVED

PAINTON of NORTHAMPTON

KINGSTHORPE, NORTHAMPTON.

Printed by SANDERS PHILLIPS & CO., LTD., The Baynard Press, Chryssell Road, London, S.W.9, and Published by BIRCH & WHITTINGTON (*Prop. Dorling & Co Epsom*], *Ltd.*), Epsom, Surrey.

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

VOL. 43 OCTOBER 1950 PART 3

CONTENTS

	PAGE
BURNHAM RADIO STATION—F. G. Balcombe and D. E. Watt-Carter, A.M.I.E.E.	117
THE LEAKAGE OF DIRECT CURRENT AND POTENTIAL GRADIENTS IN THE GROUND—P. B. Frost, B.Sc., M.I.E.E.	125
A NOVEL METHOD OF SURVEYING BOREHOLES—C. E. Palmer Jones	129
POWER-OPERATED DOORS—D. J. Harris, B.Sc.(Eng.), A.M.I.E.E.	135
EDINBURGH CONVERSION FROM NON-DIRECTOR TO DIRECTOR—W. V. McWalter	142
A SURVEY OF MODERN RADIO VALVES: Part 6a Valves for Use at Frequencies above 3,000 MC/S—W. J. Bray, M.Sc.(Eng.), A.C.G.I., D.I.C.	148
INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS	153
JUNIOR SECTION NOTES	154
NOTES AND COMMENTS	156
REGIONAL NOTES	157
STAFF CHANGES	162
BOOK REVIEWS	124, 134. 141

Price 1/6 net

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

STUDY AT HOME

You Can Have a College Training For a Few Shillings Monthly

IN YOUR SPARE TIME

CITY and GUILDS
(Telecommunication)
EXAMINATIONS

The most progressive and most successful Correspondence College in the world

To every student we send a written Guarantee of Tuition until the examination is actually passed

Our tuition is so graded that each stage is reached without difficulty.

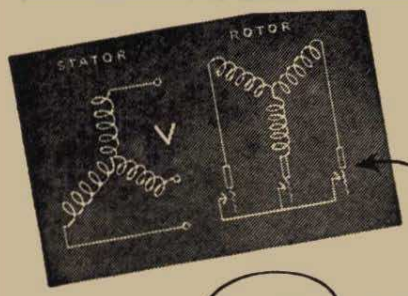
Personal attention is given to every student.

FULL PARTICULARS AND ADVICE SUPPLIED FREE.

WE TEACH BY POST IN ALL PARTS OF THE WORLD.

The Bennett College Limited

Dept. 24, THE BENNETT COLLEGE, SHEFFIELD



A.C. Polyphase Wound Rotor - Rotor Rheostat.

FOR EVERY PHASE OF ELECTRICAL WORK

The British Electric Resistance Co. Ltd. can answer the multitude of resistance problems that beset the electrical circuit designer. For twenty years Berco resistances have been giving reliable and steadfast service, and the Berco range is designed to meet every requirement.

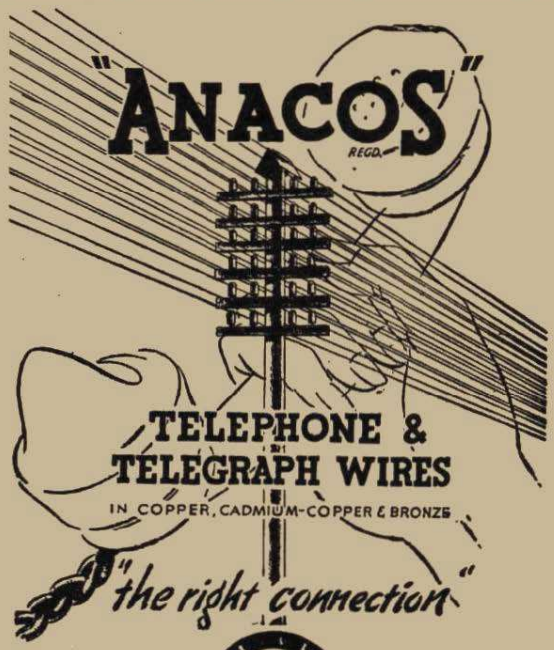
Berco engineers are specialists in resistance design and their knowledge is at your disposal.

BERCO

RESISTANCES

THE BRITISH ELECTRIC RESISTANCE CO. LTD.
Queensway, Ponders End, Middlesex
Telephone: Howard 1492 Telegrams: Vitrohm, Enfield
6R2033-AQ

"ANACOS" REGD.

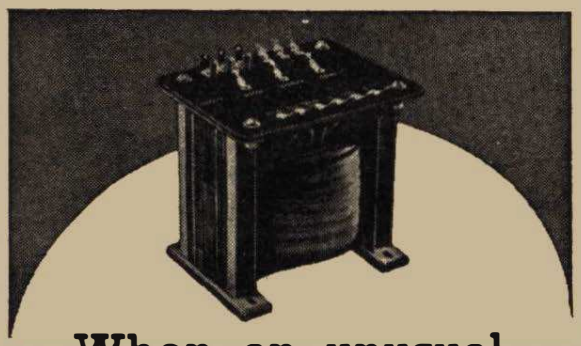


TELEPHONE & TELEGRAPH WIRES
IN COPPER, CADMIUM-COPPER & BRONZE

"the right connection"

FS

FREDERICK SMITH & COMPANY
(Incorporated in The London Electric Wire Company and Smiths, Limited)
ANACONDA WORKS, SALFORD 3, LANCS.
Phone: Blackfriars 8701 (9 lines) • Grams: "Anaconda," Manchester



When an unusual Specification is required.

We can give you the benefit of 20 years' experience in transformer construction and design. We manufacture quantities but we do NOT mass produce. Every Instrument is built to suit your most exacting individual specification.

Send your enquiries for the personal attention of our Mr. W. Bryan Savage.

TRANSFORMERS OF LIMITED
SAVAGE DEVIZES

SAVAGE TRANSFORMERS LTD. • NURSTED ROAD, DEVIZES, WILTS.

THE POST OFFICE
ELECTRICAL ENGINEERS' JOURNAL

Vol. 43 October, 1950 Part 3

Burnham Radio Station

F. G. BALCOMBE and
D. E. WATT-CARTER, A.M.I.E.E.†

U.D.C. 621.396.7

To meet modern traffic demands, the P.O. Radio Station at Burnham, Somerset, has been enlarged and re-equipped, and the new equipment was put into service in November, 1948. This article gives a brief history of the station, an outline of the traffic circulation system and a description of the apparatus now in use.

Introduction.

A LONG-DISTANCE low-frequency commercial radio telegraph service between ships at sea and this country was inaugurated in 1920 at the Post Office radio station at Devizes. By 1925 the requirement for simultaneous communication on more than one channel necessitated the provision of separate receiving and sending stations, so new stations were built at Burnham-on-Sea for receiving, and at Portishead, 19 miles away, for sending, the senders being keyed by the operators at Burnham over land-lines connecting the two stations. From that date, and especially after the later introduction of services on high frequencies (which gave world-wide coverage), the traffic grew steadily until in 1938 it reached an annual total of three million words. The station equipment and organisation at Burnham were then scarcely adequate to meet the traffic demands at peak periods. During the war, several radio stations were established overseas by other administrations to collaborate with Burnham in a unified organisation. After the cessation of hostilities, it was decided to retain these stations for post-war commercial purposes and to organise traffic to and from ships of the British Commonwealth on a new system. This system, described in the following section, and the expected increase in traffic necessitated the provision of more facilities, and a somewhat different organisation from that which the then existing equipment and accommodation at Burnham could provide, so it was decided to enlarge and completely re-equip the station.

System of Working and Facilities

Before the war there were twenty-five operating positions at Burnham for dealing with ships' radio traffic. Of these, twenty-four worked the long-distance services on low and high frequencies and the remaining one, separately accommodated, provided the usual short-range coast station services on medium frequencies, viz. telegraph and telephone communication on frequencies of 500 kc/s and 1·5 - 3Mc/s to ships within a nominal 300-mile radius. The long-distance both-way service is usually worked on six high-frequency bands, near 4, 6, 8, 13, 17 and 22 Mc/s, and the area between the inner range of satisfactory high-frequency reception (the skip distance) and the coast stations' service range is covered by the low-frequency service on 110-160 kc/s. Outgoing traffic is, however, also regularly transmitted via the high-power, very-low-frequency (16 kc/s) sender at Criggion or Rugby.

Until the latter part of the pre-war period, all operators listened for incoming calls and traffic with ships was dealt with as the ships were contacted. With the high-frequency services this method of working resulted in excessive calling and much waste of time and effort, so the "search-point" or "group working" system was inaugurated. In this system, which has proved very successful, operators work in groups, one or more groups being allocated to each frequency band, and the functions of finding ships and taking their traffic are separated. One operator in each group searches continuously for calling ships and the others deal with the traffic after the searching operator has contacted the ships. Variability of the number of traffic operators allocated to any group also contributes considerably to the success of the system. In the old building, however, group working was necessarily restricted to small teams of operators within convenient oral call of each other, so the full advantage of the system could not be obtained. Outgoing traffic for ships in all parts of the world was dealt with by direct contact and also to a limited extent by broadcasts from Rugby at fixed periods of the day, ships later acknowledging receipt of broadcast messages.

In the new system of working, the world is divided into a number of areas, each area being served by its own Area Station (Fig. 1). Each of these stations is provided with multiple sending and receiving facilities, and the overseas area stations are linked to London by high-speed, point-to-point circuits. Burnham, the area station for Area 1 (which is subdivided into Areas 1A, 1B and 1C), is linked to London by direct land-lines. All ships operating under the new system notify their movements to the appropriate area stations, and this information from all stations is recorded at Burnham in the "Ships' Bureau" where a record of each ship's position, destination, expected time of crossing into a new area or of reaching port, and similar information is kept. The outgoing traffic for ships is routed according to instructions given at the Bureau; traffic for Area 1 is

† Executive Engineers, Radio Planning and Provision Branch, E.-in-C.'s Office.

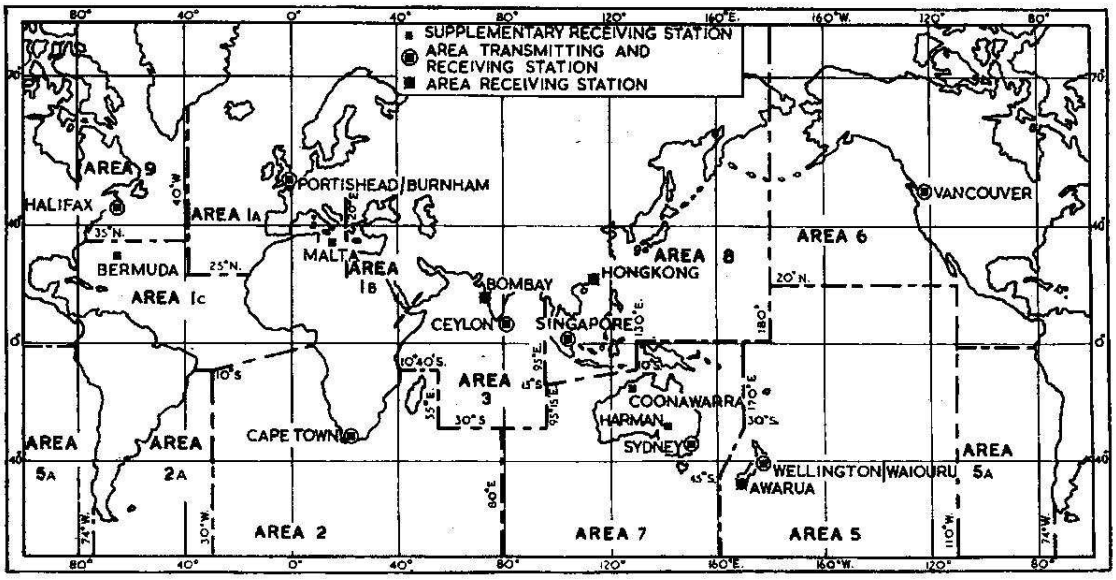


FIG. 1.—AREAS, AREA STATIONS AND SUPPLEMENTARY RECEIVING STATIONS FOR LONG-DISTANCE SHIP-SHORE RADIOCOMMUNICATIONS.

broadcast at four-hourly intervals from the Portishead and Criggion (or Rugby) radio stations under control from Burnham, and that for other areas is forwarded to the appropriate area stations for inclusion in their broadcasts. Traffic from British Commonwealth ships within Area 1, and also world-wide traffic to and from ships which do not work within this system, e.g. foreign ships, is dealt with in the original way, that is each ship calls or is called and after two-way communication is established, the messages are passed.

With the resumption of radiotelegraph service to and from ships at sea, the traffic rose rapidly above pre-war level, and better facilities were required for traffic control and for the development of the group working technique. It was to meet these requirements and to improve the general receiving facilities that the station was re-equipped.

Working Facilities.

For group working in the high-frequency bands, the search-point operators require continuous omnidirectional reception, and each traffic operator also needs the best practicable reception from any direction he may select at any moment. Omnidirectional aerials and a fan of relatively high-gain aerials with a special aerial distribution and selection system were provided to enable each operator to select the appropriate aerial for reception of the traffic with which he is concerned at the moment. Aerials can be used simultaneously by any number of operators without interaction.

For answering ships and sending traffic, all operators require quick and easy sender control and keying facilities. Access to and keying of senders can be effected by the operation of lever-type and morse keys provided at each operator's position, and since the operators in one group generally share the use of a sender, a system for giving engaged signals is also provided. Team working in a group necessitates immediate communication between the members who may not always be within convenient oral call of each other, and also necessitates means of advice to the search-point operator when members of his group are free to take traffic. To meet this and all the other intercommunication requirements of the station, a special system giving very comprehensive facilities was provided, which, in addition to the facilities mentioned above, gives flexibility in the number of traffic operators allocated to any searching operator and direct communication between all operators and the circulation control position.

For low-frequency working, high-gain receiving aerials are unwarranted, and the best reception is frequently obtained by directional discrimination against unwanted signals. Crossed-loop aerials, which may be used omnidirectionally or directionally, and a distribution system enabling all four L.F. operators to use the aerials simultaneously and independently were, therefore, provided. Sender control and intercommunication facilities similar to those for the H.F. operators were also provided although group working is not at present used. All operators are provided with modern high-grade communications-type receivers.

The outgoing traffic for Area 1 has to be broadcast at fixed times of day, and accordingly it is necessary that the operators at the broadcast positions have overriding control of the senders. The sender control circuits throughout the station are, therefore, so arranged that exclusive control by the broadcast operators can be effected.

For general traffic circulation and control, facilities are required for the rapid reception or despatch of traffic over the inland network; quick circulation of message forms within the station via the circulation control point and Ships' Bureau (where distribution, checking and overall control are effected, and routing instructions given); rapid intercommunication between all staffed points and ready availability of

shipping information at the Bureau. To meet the traffic circulation requirements, traffic over the inland network is received and despatched by twelve teleprinters, and for internal traffic circulation conveyors link the circulation control tables with the operators' positions in each wing of the building. Shipping information is available in a visible index record at the Ships' Bureau and a pictorial presentation of the locations and courses of ships at sea is provided by movable arrows on three large wall charts.

The layout of the station and a more detailed description of certain of the above-mentioned provisions are given in the following sections.

receiving positions for long-distance ship-to-shore traffic. The far end of Wing B accommodates six receiving positions equipped for medium-frequency Coast Station services, and the remainder of Wing B is occupied by teleprinter and broadcast positions. The central control room contains the traffic circulation control positions, the Ship's Bureau and the P.B.X. The building is well lit, both naturally and artificially, and the room noise caused by the operation of typewriters and teleprinters is materially reduced by acousti-cellotex tiles lining the ceiling, and insulation boarding lining the walls of all three wings. There is a V-belt conveyor running centrally through

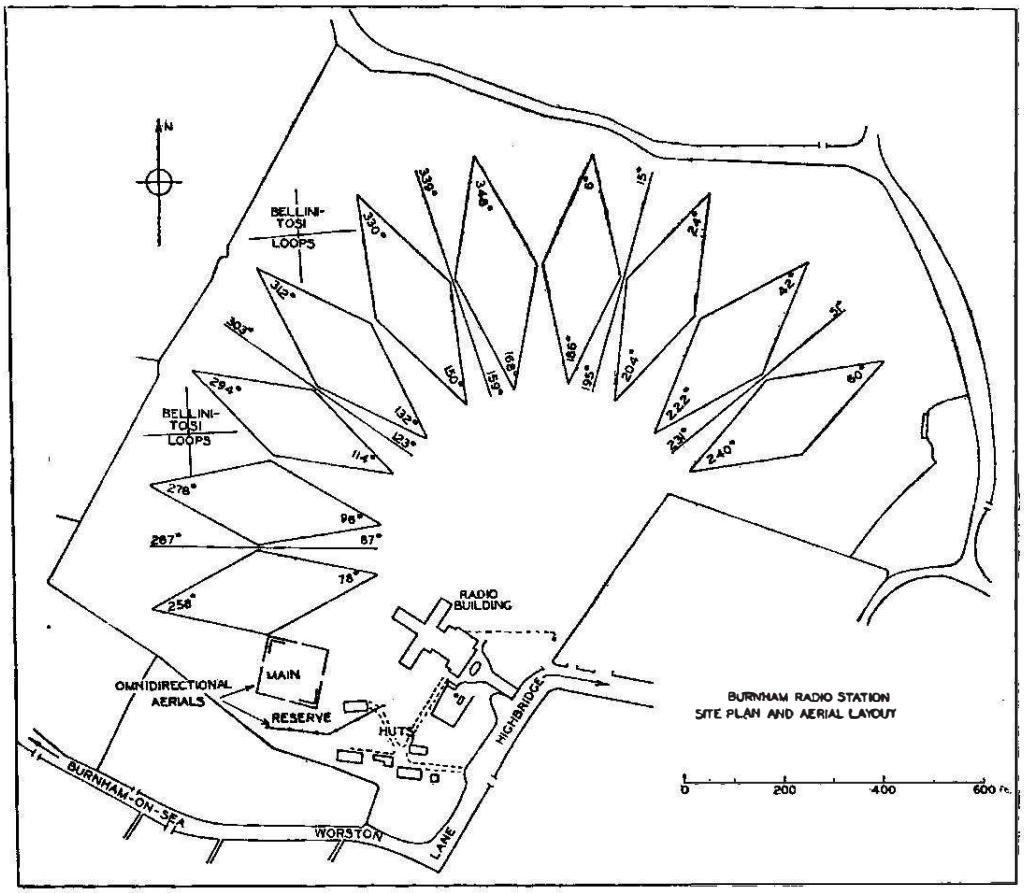


FIG. 2.—BURNHAM RADIO STATION SITE PLAN AND AERIAL LAYOUT. (M.F. AND MISCELLANEOUS AERIALS OMITTED).

STATION LAYOUT

The re-equipping of the station entailed constructing a new building, installing modern equipment, augmenting the power supplies, extending the site, constructing a new aerial system, and scrapping the heterogeneous collection of old internal and external plant. To accommodate the aerial system, which is illustrated in Fig. 2, the site area had to be approximately quadrupled. The new building, illustrated in Fig. 3, consists of three wings, each 60 ft. × 24 ft., constructed in standard prefabricated hutting and radiating at right-angles from a 35 ft. square central control room. Wings A and C accommodate the 32 each wing and a flat-band conveyor mounted above the V-belt conveyor in Wing B to facilitate the distribution of messages.

The Wall Charts.

The wall charts are illustrated in Fig. 4. The largest is 14 ft. × 31 ft. 6 in. and shows the world in Mercator's projection between latitudes 65° North and South. Two smaller charts, 14 ft. × 12 ft., show, to a larger scale, the more congested areas of the North Atlantic and of the coastal waters round the British Isles. They are painted on steel plates, and magnetic arrows carrying the ship's call sign are used to indicate

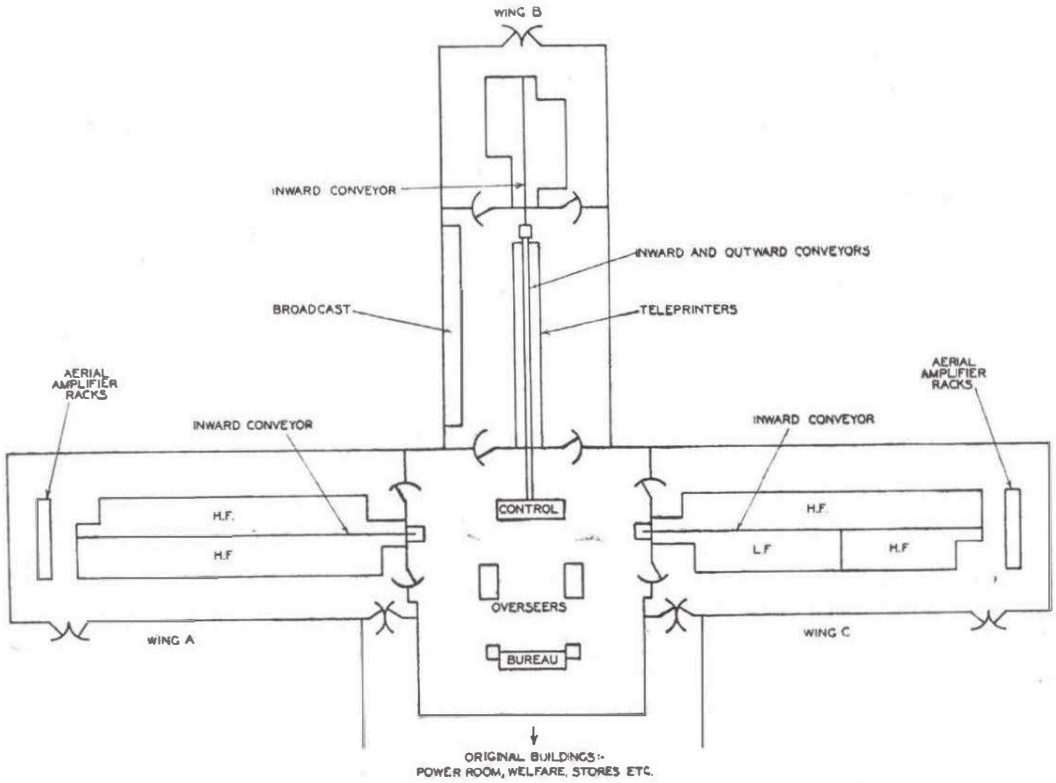


FIG. 3.—PLAN OF NEW BUILDING.

on the charts the position and course of ships. Under exceptional conditions, e.g. accident at sea, these charts may be a vital necessity as they enable the ships' movements to be better visualised and therefore better controlled.

HIGH-FREQUENCY RECEIVING EQUIPMENT

Aerial System.

The H.F. aerial system is arranged to receive signals in the frequency range 4 to 22 Mc/s from all parts of the world. All-round coverage combined with the highest practicable directivity gain is achieved mainly by the use of a number of horizontal rhombic aerials. This type of aerial can be designed to have a suitable directional response throughout most of the required frequency range and, because of its relatively uniform impedance-frequency characteristic, it is well suited to operate in conjunction with the

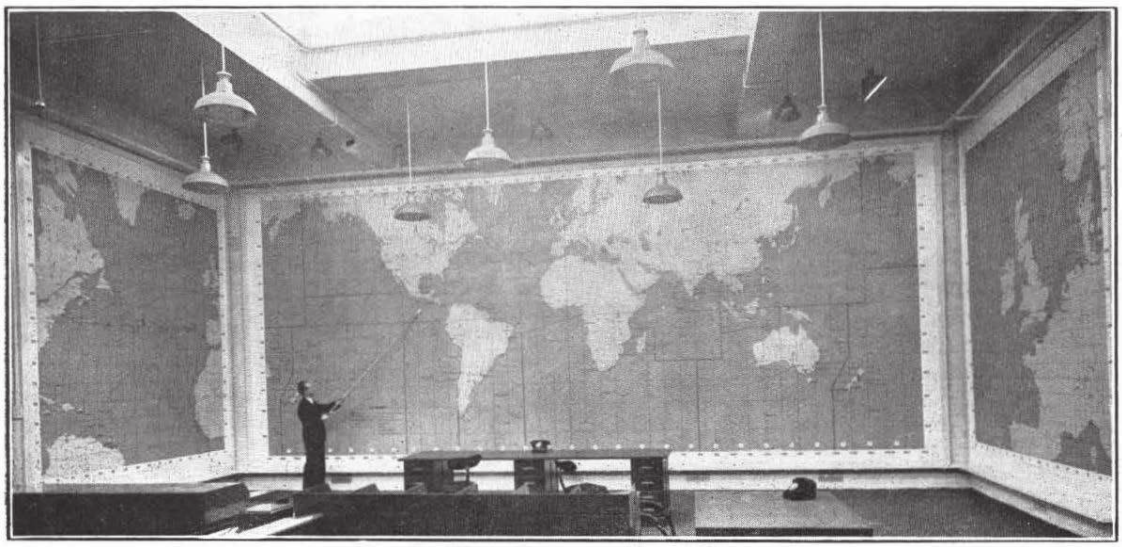


FIG. 4.—WALL CHARTS IN SHIPS' BUREAU.

distribution system described later. For a rhombic aerial to operate efficiently, it must be terminated resistively in its characteristic impedance at the end remote from the receiver. If this termination, which for unidirectional working takes the form of an absorbing resistor, is replaced by a second receiver correctly matched to the aerial at all frequencies, the wanted input signal to the first receiver is unaffected, and since the arrangement is symmetrical it will be seen that by connecting both ends of each aerial to the receivers via the distributing system (which is designed to effect the necessary matching) it is possible to obtain simultaneous bi-directional reception on each aerial, resulting in a 50 per cent. saving in the number of aerials required. Ten such aerials, each of side-length 246 ft. and side-angle 140°, have been erected at a height of 102 ft. above ground, each aerial serving two diametrically opposed zones 18° wide. It will be seen from Fig. 2 that the rhombic aerials are arranged fanwise in a semi-circular arc round the station, this arrangement effecting maximum economy in site area and supporting structures, as well as ensuring a reasonable degree of freedom from mutual interference between aerials. Interspersed with the horizontal rhombic aerials, there are five vertical bi-directional half-rhombic aerials, of the same side-length and side-angle, which supplement the performance of the former, particularly at the lower frequencies where the response of the horizontal aerials to signals arriving at very low angles is poor. Since the horizontal and vertical aerials respond predominently to waves polarised in their own plane, and in practice an electromagnetic wave tends to become randomly polarised after ionospheric reflection, the two aerial systems are complementary.

In addition to the directional aerial system, a number of omnidirectional aerials are provided, primarily for use at the search-point receiving positions. The omnidirectional aerials consist of six horizontal V-dipoles, and as a reserve in the event of storm damage there are six separately supported vertical dipoles. The aerials are all of the multi-wire cylindrical cage construction and sufficiently aperiodic to enable one aerial of each type to cover one frequency band.

Distribution System.

The signals received from ships lie in six discrete frequency bands and the aerial-to-receiver distribution system, which is shown in Fig. 5, is designed to distribute the signals from any of the aerials to any combination of the thirty-two receivers. This is done in the case of each rhombic aerial by amplifying the signals in a multi-band amplifier, then distributing them at equal level to all receiving positions by means of transformers and resistance networks, and finally connecting each receiver to an appropriate aerial by selective switching. In this installation it is the amplifiers which serve as terminating impedances for the double-ended rhombic aerials, and to ensure a good front-to-back aerial response ratio the amplifiers must each have a substantially constant resistive input impedance. They must also effect a good compromise between contribution of noise, distortion due to overload, and gain to offset the loss of the distribution network. The design adopted has six narrow pass-bands corresponding to the ships' bands, each band being separately amplified. This allows a low-noise valve to be used without danger of overloading it by unwanted signals, and still permits the input coupling arrangements to give a satisfactory impedance characteristic. The noise figure achieved is approximately nine times, and the gain of the amplifier is approximately 25 db.

The distribution system is divided into two for economy and convenience in cabling Wings A and C of the building. This division is effected by a resistive network, and then the output to each half is transformed from 75-ohm to 10-ohm impedance to which twenty outlets to receiving positions are connected. Series and shunt 150-ohm resistors in each outlet provide adequate buffering against the impedance variations at the receiving positions (where variations from practically short-circuit to open-circuit occur) and against possible whistles due to the coupling of the receiver inputs. The distribution of signals from the omnidirectional aerials differs from that for the rhombic aerials, only in that prior to amplification the signals from all of the six aerials are passed through a combining unit which prevents interaction between the aerials and provides a suitable input for the standard amplifier which follows it. Receivers are connected to the appropriate aerials by selective switching, the first switch permitting the selection of directional aerials or omnidirectional aerials; if directional reception has been selected, then by a second switch horizontal or vertical aerials may be selected; a third switch, which is continuously rotatable and marked with the cardinal points of the compass, is used to select any particular direction. The system is working very satisfactorily, cross-modulation and blocking due to unwanted signals is

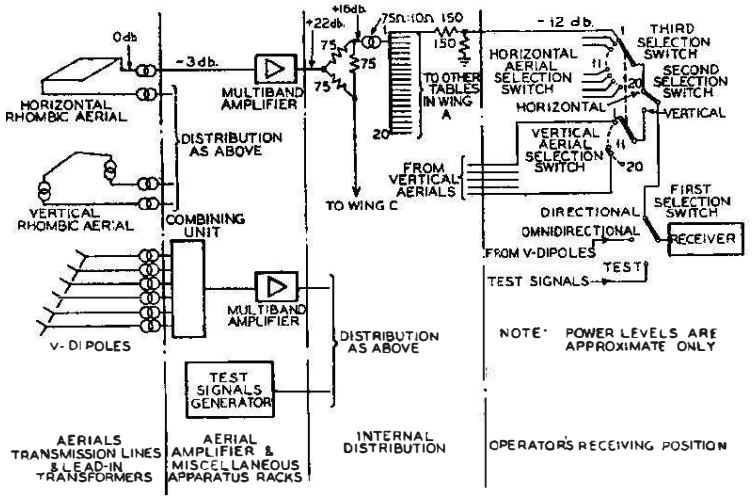


FIG. 5.—H.F. AERIAL DISTRIBUTION SYSTEM.

no worse than in direct reception, and the cross-talk ratio for signals on the same frequency, but from different aerials, is at least 20 db.

To give an indication to the operators of the sensitivity of their receivers, and to serve as a frequency calibration, low-level test signals from crystal oscillators are available at each position. There is one such test signal lying near the middle of each frequency band and it is keyed with continuous dots to differentiate it from any other signals. The level of these test signals at the receiver input is 1 μV and when the 5 kc/s intermediate frequency bandwidth is used, this gives approximately 20 db. signal-to-noise ratio in the receiver output. Higher level test signals are available to engineering staff for checking automatic gain control and limiting action.

Receiving Positions.

The layout of a traffic operator's H.F. receiving position, of which there are twenty-eight, can be seen from Fig. 6. The receiver is the Marconi Type CR 150

FIG. 6.—RECEIVING POSITIONS IN WING C.

communications receiver, and immediately on its right is the switch panel for aerial and test signal selection. On the right of the operator's chair is the sending key with its associated send-receive switch, the microphone for inter-communication purposes, and the sender control box with two additional keys at the bottom for intercommunication. Search points are equipped with a switchboard similar to the sender control box, for intercommunication. The conveyor for transporting incoming radiograms to the central control room can be seen dividing the two lines of tables.

Four positions are equipped for high-speed morse reception from such ships as the R.M.S. *Queen Mary* or *Queen Elizabeth*. For this service, which works at about 100 bauds, the single-tone output signals from the receiver are fed into a thermionic relay which has facilities for re-shaping signals by curbing or limiting, and correction of signal bias; the double-current output from this relay is then used to operate an undulator.

LOW-FREQUENCY RECEIVING EQUIPMENT

Aerial System.

The L.F. aerials are a non-resonant T-aerial provided for reserve purposes, but used when noise and interference are low, and two sets of Bellini-Tosi crossed-loop directional aerials for use when interference or noise is troublesome (one set being a reserve in case of damage to the other). The loops are triangular, the base being 204 ft. and the height 84 ft. Each pair is supported at the centre by a 105-ft. tubular steel mast and at the sides by 16-ft. poles, and is connected to two 600-ohm balanced transmission lines by transformers housed in a weatherproof metal box at the base mounted near the mast at a height of 10 ft. The transmission lines, which extend for approximately 900 ft. to the building, are run on the diagonals of a square to reduce interaction to a minimum. A separate sense aerial is not provided, the signals for sense purposes being derived from the combined pair of loops through a third transformer and transmission line, the latter being run above and well separated from the other two lines.

The medium-frequency coast station requirements are met by the provision of two quarter-wave vertical aerials resonant at 1,300 kc/s and 3,000 kc/s, and one non-resonant inverted-L aerial for the 500 kc/s frequency band.

Aerial Distribution.

The L.F. aerial and distribution system provides for directional aerial reception at each of four operators' positions. The polar diagram of the directional aerials is a cardioid, and each operator can adjust his null direction without affecting the others. Individual control of the amplitude and phase angle of the sense signal, which is necessary for the attainment of a good null, is provided in a local amplifier, which also produces the 90° phase shift needed to produce a cardioid polar diagram. The arrangement is shown in Fig. 7, from which (for simplification) the switching for producing omnidirectional and figure-of-eight characteristics has been omitted. These characteristics are produced by normal direction-finding technique.

The gain of the loop amplifiers is approximately 25 db. and the gain of the sense and the operators' amplifiers in tandem is variable between 12 and 25 db. The phase-shift control enables a change to be made of approximately plus or minus 33° throughout the frequency band, this wide control of phase angle being necessary due to departure from plane vertical polarisation of the received waves. As the losses in the aerial, the transmission lines and transformers are small, and the gains of the amplifiers exceed the subsequent losses in the distribution system, any

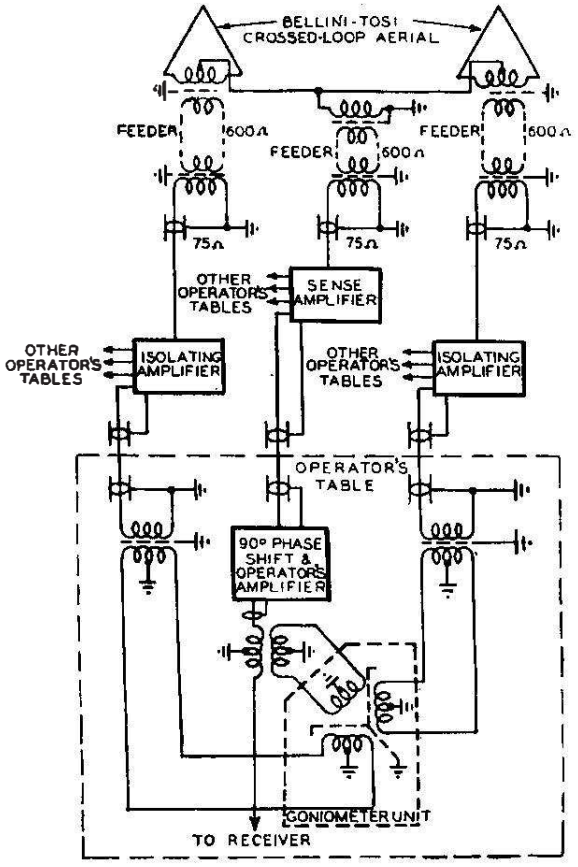


FIG. 7.—L.F. AERIALS AND DISTRIBUTION SYSTEM.

degradation of signal-to-noise ratio will be dominantly due to the amplifiers. The result achieved is that signals received in the presence of the minimum radio noise will be degraded by not more than about 1 db. when using the receiver bandwidth of 300 c/s. For most of the time the radio noise field will be higher and the degradation correspondingly less. The maximum to minimum ratio obtained by the goniometer depends on the direction of the signal but is at least 30 db.

Receiving Positions.

The four L.F. receiving positions differ little from the H.F. positions. A Marconi CR 100 receiver is used instead of a CR 150, and a goniometer with polar-diagram selection keys and a sense amplifier replace the aerial selection switches. Two positions are equipped for high-speed reception.

SENDER CONTROL

The remote control from Burnham of the senders is normally restricted to keying only, but some senders can also be switched on and off and their frequencies changed by remote control. The main group of senders is located at Portishead, and the control of these is effected over two 12-channel V.F. systems supplemented by a telephone order wire. Control of the V.L.F. sender at Criggion or Rugby is effected over V.F. channels via the Central Radio Office in London.

Since most of the outgoing traffic is broadcast, and is therefore controlled from the broadcast positions in Wing B, incoming traffic will normally preponderate at the positions in Wings A and C where a number of operators may, therefore, share the use of a sender for answering ships and for other purposes. Usually one group, headed by its search-point operator, operates on one marine frequency band, and one sender is allocated to that group. Any operator in a group can throw his sender key which links him to the sender allocated to his group, and when he wishes to transmit, his send-receive switch is thrown to "Send," which connects his Morse key to the keying circuit and also gives an engaged signal at all other operators' positions sharing the use of the sender. If the sender is already being keyed, the throwing of his send-receive key to "Send" causes his engaged-signal lamp to follow the signals being sent, thus enabling him to gauge when the sender will be free again. For this system of paralleled keys, single-current transmission is used in the local circuits, the conversion to double-current working for operation of the V.F. equipment being effected in bridge networks which also provide the monitoring signals for the warning lamps.

The control of all senders is generally available at all positions, but the circuits are arranged to permit the uninterrupted use of certain senders for broadcast transmission at specified periods of the day. Warning is given by a flashing signal on the control box at each receiving position when broadcasting is about to start, and this signal becomes a permanent glow when the circuit is finally taken by the broadcasting operators.

INTERCOMMUNICATION SYSTEM

The success of the group system of operating depends largely on easy and rapid communication both between search-point operators and their working operators, and between the central control position and all operating and information points. This is provided by the telephone network indicated in Fig. 8. Where headphones are normally worn, i.e. at the traffic and search points, one of the earpieces can be switched into the intercommunication network, thus never isolating the operator from his receiver. At the broadcast and central control positions a loudspeaker is used. The search-point operator can switch-in to a receiving point and speak without delay, as in order-wire working, and to ensure immediate attention a visual signal is given at the receiving point. At the central control position (the traffic circulating centre, normally manned by two controlling officers) twin 40-key switchboards are fitted, giving direct access to all operating and information points. At operating points the intercommunication equipment is incorporated in the sender control unit, and at search-points a small 20-key switchboard is fitted. The system is flexible, for search-points can switch out their auxiliary equipment and operate as traffic points, and each search-point can include any traffic operating point in his group, provided only that it is in the same wing of the building. Moreover, a group of traffic working points can be shared between search-points, i.e. a pool of relief traffic operators can be

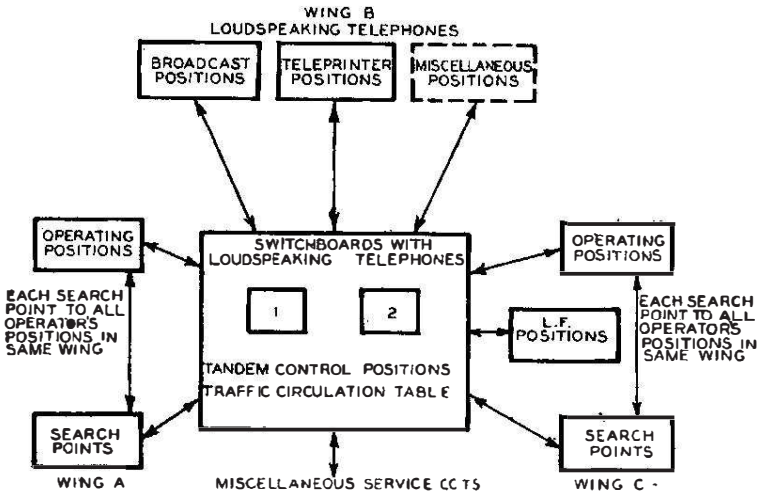


FIG 8.—THE INTERCOMMUNICATION SYSTEM.

formed when traffic is fluctuating. Experience of working the station has shown that the facilities have effected a great improvement in the station operating technique.

Conclusion.

The annual traffic handled at Burnham rose from less than a million words in 1926 to three million words in 1938, and to seven and a half million in 1949. The increase in traffic handled is an achievement which reflects considerable credit both on the administration and the operating staff, for the latter have often had to work under difficult and trying conditions, especially at Christmas time when traffic rises to several times the normal. The re-equipping of the station has considerably eased the work of the staff and has provided appreciable margin to meet further increases in traffic.

The authors wish to acknowledge the assistance received in the preparation and checking of this article from their colleagues in the Engineering Department and Wireless Telegraphy Section.

Book Reviews

" Communication Circuits." Third Edition. Lawrence A. Ware, E.E., Ph.D., and Henry R. Reed, M.S., E.E., Ph.D. Chapman & Hall, London. 403 pp. 174 ill. 40s.

This is a new edition of a book which is already well known in this country and it includes considerable additions and improvements. The title may be misleading to those not familiar with the earlier editions; in the author's own wording the contents cover " the basic principles of communication transmission lines and their associated networks covering the frequency range from voice through ultra-high frequencies and using the M.K.S. rationalised system of units."

The first third of the book is concerned with conventional transmission line theory and the evaluation of the primary coefficients including skin effect and proximity effect in coaxial and balanced pairs; the essential modified Bessel Functions are introduced in Chapter 1, and a more detailed study of their derivation is relegated to an Appendix. Two chapters are devoted to filters but do not venture beyond Zobel designs; impedance matching via pads and reactive T-sections is then dealt with and this leads up to the use of matching stubs in H.F. lines.

The remainder of the book is concerned with wave guides and the electromagnetic theory of coaxial lines. These are dealt with conventionally and include some information on methods of excitation. The field equations for the guides are carefully developed and are supplemented by an Appendix giving a clear and concise derivation of Maxwell's equations in differential form, for both cartesian and cylindrical co-ordinates.

The book is well written and carefully arranged, and should be of considerable value to the student who wishes to cover thoroughly the subject of transmission theory. Each chapter includes copious numerical exercises and a final chapter sets out 12 experiments designed to lend understanding to the subject matter of the book. R. J. H.

" Matrix Analysis of Electric Networks." P. Le Corbeiller. Harvard Monographs in Applied Science, No. 1. Harvard University Press, 1950. Chapman & Hall. 108 pp. 49 ill. 24s.

The application of matrix algebra to the analysis of complicated networks results in a great simplification of the mathematics involved: for matrix algebra provides the machinery to generalise from simple individual cases to complicated groups and systems. The object of this little book is to present to engineers a simple approach to Gabriel Kron's matrix method of network analysis.

The elements of matrix algebra, stripped of all unessential mathematics, is given in the first chapter. Of particular interest is the demonstration of the rule for determining the elements of the inverse of a matrix and the discussion of its application to specific types of network problem.

In the second chapter an original derivation of Kron's mesh-method formulæ is given: by introducing the idea of an " intermediate " network, the author shows clearly how Kron's square non-singular matrix M passes into the rectangular singular matrix C. The same type of reasoning is applied in the third chapter to the dual problem of analysing a network on a mode-pair (instead of a mesh) basis; and the discussion is illustrated by applications to bridge networks and triode-coupled circuits with inter-electrode admittances.

The fourth and last chapter discusses the final achievement of Kron's method in the field of stationary networks, namely, the analysis of a system in which both voltage and current sources are connected to branches coupled to each other in the most general way.

This book can be warmly commended to those who wish to master Kron's matrix method of network analysis. The reader who has mastered this theory will find himself capable of analysing complicated networks having any number of symmetric or asymmetric couplings and connected to voltage and current generators in any conceivable way. H. J. J.

The Leakage of Direct Current and Potential Gradients in the Ground

P. B. FROST, B.Sc., M.I.E.E.†

U.D.C. 620.193.7 : 621.315.2 : 621.3.014.6

Corrosion of P.O. cables by leakage currents from tramway systems and electricity supply networks is a serious and widespread problem requiring constant attention. It is important that the basic considerations applying to current leakage and ground potential gradients be widely appreciated and this article explains in simple terms the principal factors concerned and illustrates methods adopted to reduce this type of corrosion to a minimum.

Introduction.

THE study of the flow of direct current in the ground involves conceptions not very generally understood. The earth is a poor and variable conductor, yet the cross-sectional area of the path traversed by a direct current is, at a distance from the electrode, extremely large. There is no means of confining the current to any restricted path; the resistivity of the soil, the subsoil and lower rock strata vary over extremely wide ranges and the conductivity of the upper layer is greatly modified by the presence of buried metal pipes and other such conductors.

Any attempt to predict the course or intensity of the current flow at any point between two earth electrodes which are buried in the ground remote from one another is thus beset with considerable difficulties.

The conventional forms of earth electrode, plates, plates in coke, strips, pipes or driven rods are all intended to provide a large contact area with the ground, but the greatest economy is attained by distributing the electrodes over a wide area and connecting them in parallel.

Quite as important as the actual resistance to earth of an earth electrode system is the potential gradient around such an electrode when a heavy current is passing. Under these conditions the equipotential curves around an electrode system can be plotted by surface measurements with a high resistance voltmeter connected between an exploring spike and a remote earth connection. The total drop of volts between the electrode and earth is a function of the current and the total resistance to earth, but the potential gradient depends upon the form of the electrode, being greatest in the close vicinity of a single earth rod. Equipotential curves will rarely be concentric circles owing to their distortion by variations in the resistivity of the soil and the presence of conducting pipes or cable sheaths.

Cattle are not infrequently killed by bridging ground potentials caused by current flowing from earth electrodes, but steep potential gradients can be avoided by sinking an earth electrode well below the surface of the ground and using an insulated cable to make connection with it.

In making measurements of the P.D. between a cable sheath or metal pipe and ground, it is important to remember that when the ground is carrying current its potential may be raised above or depressed below that of the general mass of the earth. Thus, the potential of the earth adjacent to a tram rail carrying current may approach that of the rail whereas in the footway it may not differ very much from that of the general mass of the earth. The potential of the rails may be extended to the footway by the practice of bonding iron standards to the rails or by water mains or cable sheaths which cross the road below the track. A network of bare lead cables in damp ducts forms one extensive conducting whole and has a very low resistance to earth. Differences of potential between different points in this network can only arise when currents are flowing in the sheaths and such currents are often picked up from the ground, to which they leak from uninsulated tram rails or from leaky mains.

The conductivity of cable sheaths is relatively high, but the P.D. between different points on the cable due to sheath currents is generally low. Indeed, it is found that far higher P.D.s exist between different points in the ground than exist between different points in the cable network.

In a town containing ramified networks of metal pipes it is no easy matter to select a site for placing an earth electrode intended to act as a reference of zero potential, since such a point must be remote from all buried conducting pipe systems.

Leakage from Tramway Systems.

The diagrams which follow are based on theoretical considerations but serve as a basis for the study of the conditions arising from the presence of tramway systems with uninsulated rail returns and from faults on power distribution mains.

Arrows are used to indicate the flow of current from the contact conductor through the motors to the rails, from the rails to the ground and from ground to cable sheath: they also indicate where current leaves the cable sheath and flows through the ground to the rail, to return to the power source.

The term "true earth" denotes a reference earth so remote from the track and all buried metal structures, such as extensive pipe systems which approach the track at any point, as to be substantially at zero potential. "Local" earth potential is the potential of the ground in close proximity to the conductor under consideration, which, in the following discussion, is generally the P.O. cable.

Fig. **1** shows a long, uninterrupted bare lead-sheathed cable laid parallel with, and at a uniform distance from, a single tramway track loaded by a single concentrated load at the end remote from the supply station—the soil is assumed to be homogeneous. The tram rails are uninsulated from the ground but are assumed not to be earthed deliberately at any point by connection to conventional earth plates: the rails thus assume a potential above that of true earth at their distant end and below that of true earth at the station end.

†Formerly Staff Engineer, External Plant and Protection Branch, E.-in-C.'s office.

The potential of the cable is above true earth at the distant end and below true earth at the station end. On the other hand, the potential of the cable is below

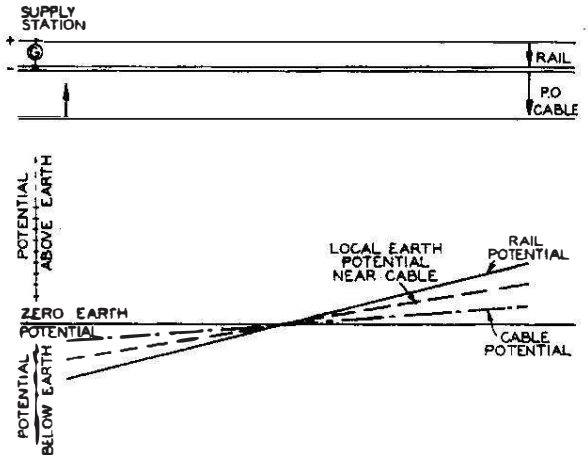


FIG. 1.—SINGLE CONCENTRATED LOAD AT FAR END OF TRAMWAY.

that of local earth at the distant end and above that of local earth at the station end. That is why current flows from the ground into the cable at the distant end and leaves the cable and flows into the ground and thence to the rails, at the station end.

In Figs. **2** and **3** the vertical intercepts between the curve of cable potential and that of local earth

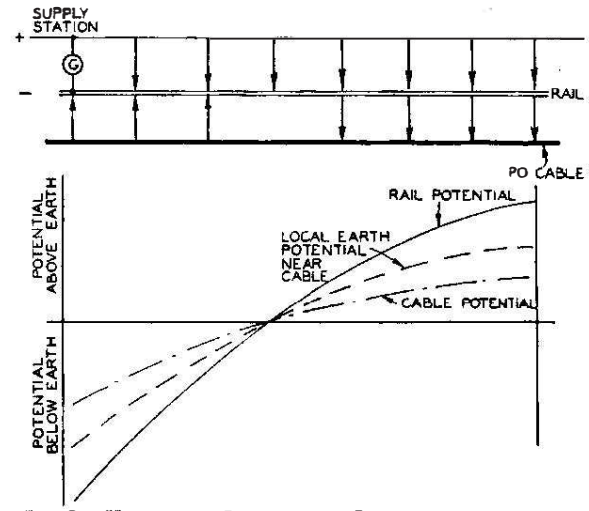


FIG. 2.—UNIFORMLY DISTRIBUTED LOAD ALONG TRAMWAY.

potential indicate the magnitude and direction of the P.D.s which cause current to pass from cable to earth or vice versa. The magnitude of these currents also depends upon the resistance between cable and earth, and when this is high (e.g. due to a dry duct) it is not uncommon to find high values of P.D. between cable and local earth but an insignificant flow of current.

Fig. **3** indicates how the P.D. between cable and local earth is reduced by the use of gaps : the result is that the exchange of current between cable and earth is minimised and so the risk of corrosion is reduced. The pick-up and discharge areas are now distributed

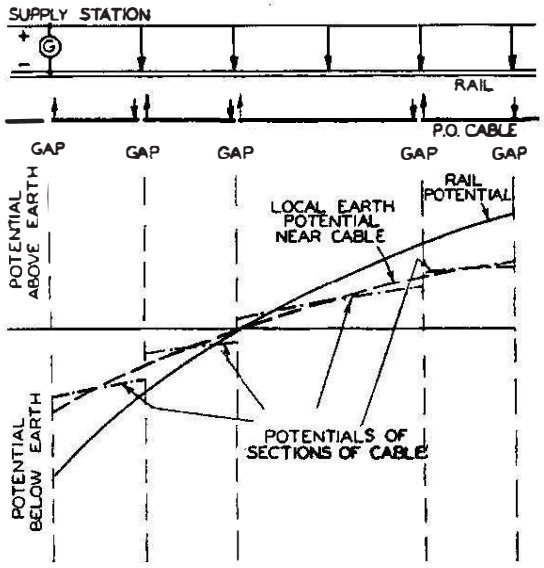


FIG. 3.—UNIFORMLY DISTRIBUTED LOAD. INSULATING GAPS IN P.O. CABLE.

over the length of the cable and if the number of gaps was very large the risk of corrosion would be negligible. Other obvious drawbacks would, however, arise.

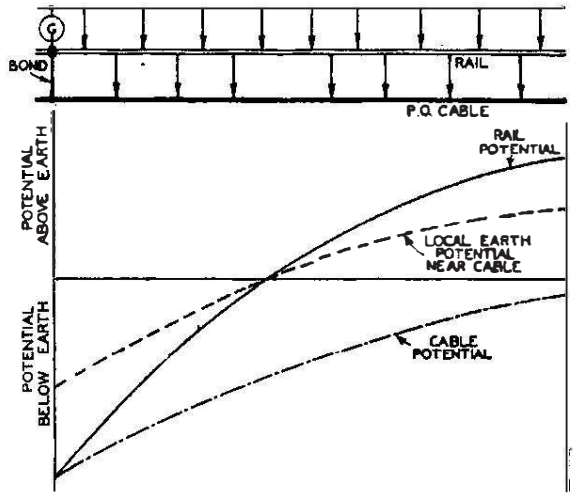


FIG. 4.—UNIFORMLY DISTRIBUTED LOAD. P.O. CABLE BONDED TO RAIL.

In Fig. **4** the P.O. cable is bonded direct to the station end of the rail. The effect of the bond or " drainage " connection is to increase the current in the cable and to make the cable negative to local earth throughout its length. Under these conditions, in general, no corrosion would occur. Drainage bonds used indiscriminately may, however, result in dangerously heavy currents being carried by the P.O. cable sheath. Drainage bonds cannot be safely used where some sub-stations are shut down at night, as this condition entirely alters the distribution of potential and leads to increased danger of corrosion.

Fig. 5 illustrates the conditions arising when the P.O. cable is bonded through a resistance to the station end of the rail. The resistance is such as to bring that end of the cable to the potential of local earth—elsewhere it is negative to local earth. The

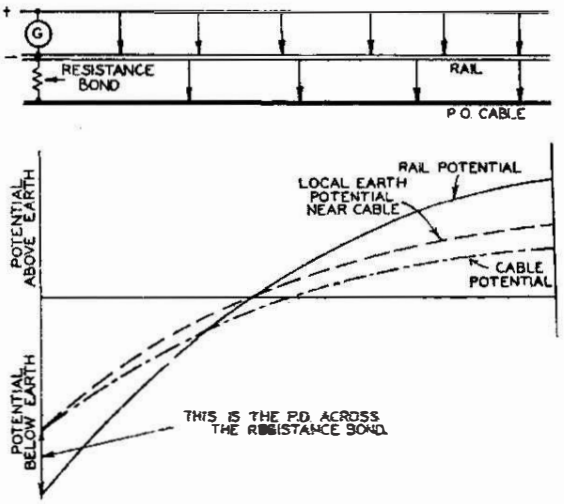


FIG. 5.—UNIFORMLY DISTRIBUTED LOAD. P.O. CABLE BONDED TO RAIL THROUGH A RESISTOR.

cable carries less current than in Fig. 4 and, in general, no corrosion would occur, but adjustment of the value of the resistance bond is necessary to meet changes in the loading on the system. A further alternative is illustrated in Fig. 6 in which the P.O. cable is in-

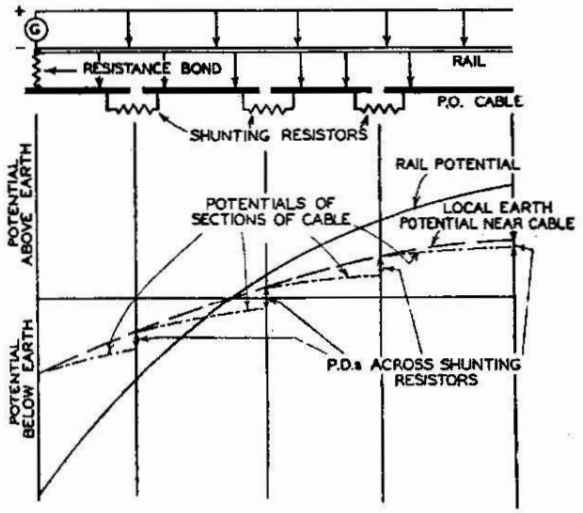


FIG. 6.—UNIFORMLY DISTRIBUTED LOAD. GAPS IN P.O. CABLE SHUNTED BY RESISTORS.

terrupted by insulating gaps in three places, each gap being shunted by a resistance adjusted so that during normal conditions the P.D. between each cable section and local earth is zero at the end nearer the station. The effect is to reduce the current carried by the cable sheath still further than in Fig. 5, whilst still eliminating all discharge areas. The average P.D. between each cable length and local earth is, however, much reduced. This is an advantage since in certain soils a high negative P.D. to earth can lead to corrosion. For a given tramway load this arrangement is very nearly perfect, but tramway loads vary over the 24 hours and during light load some stations may be shut down. Such variations in operating conditions call for the use of pilot wires and recording voltmeters, and even the adjustment of the resistance bonds from time to time. Fig. 7 shows the cross-

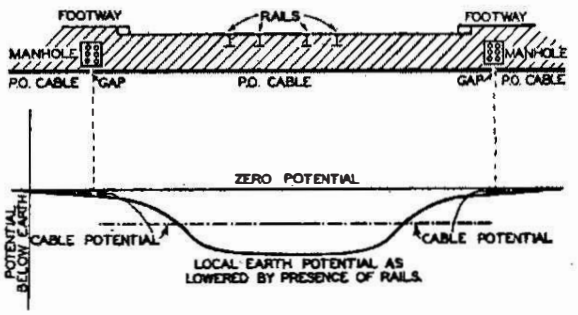


FIG. 7.—CROSS-SECTION OF ROAD SHOWING EFFECT OF TRAMWAY ON CABLE CROSSING UNDER TRACK.

section of a tramway route and a P.O. cable in earthenware duct crossing under the track. The cable is separated from the general network by insulating gaps at manholes on each side of the road, and the potential it takes up is a rough mean of the potentials of the different portions of ground which it traverses.

The diagram applies to a section of the track at which current is returning from the ground to the rail, and here the isolated length of cable will be negative to local earth at both ends but positive to local earth elsewhere. Owing to its short length it has a comparatively high resistance to local earth, and any current flow from the cable will be so small as to involve little risk.

If the gaps were short-circuited the cable sheath would assume a potential approaching that of the cable network as a whole, i.e., of the general mass of the earth (zero potential) and a considerable flow of current from the cable sheath to local ground would occur beneath the track—especially when the dip in the duct was full of water.

The effect of the variation in distance between the cable in the footway and the tram rails is illustrated

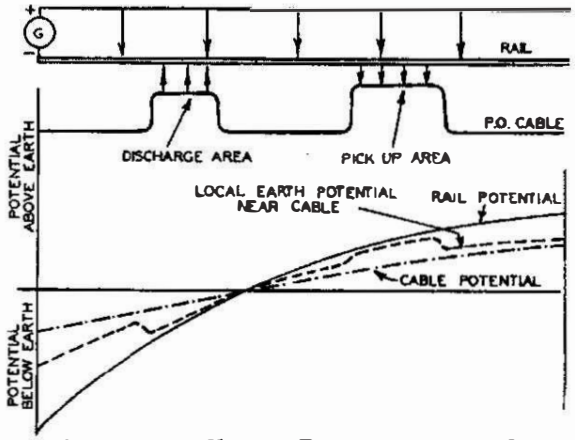


FIG. 8.—EFFECT OF VARYING DISTANCES BETWEEN CABLE TRACK AND TRAMWAY.

in Fig. 8. Such conditions arise where the carriageway narrows in certain places. The steep voltage gradient near the rails accentuates the effect of these variations in distance.

Leakage from Supply Mains.

Fig. 9 refers to the case of a leakage on the *negative main* of a three-wire system. The neutral of the

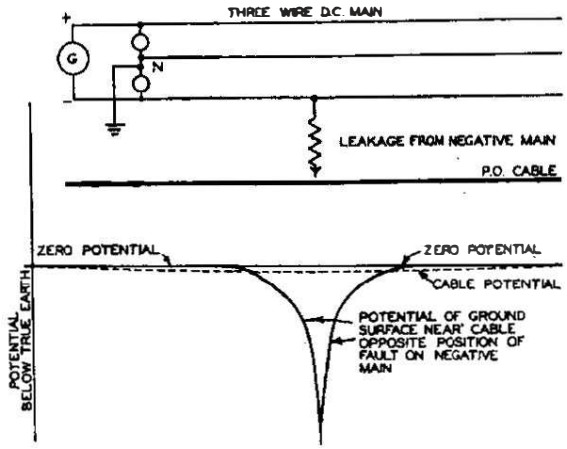


FIG. 9.—LEAKAGE FROM NEGATIVE MAIN OF 3-WIRE SYSTEM.

system is earthed and the P.O. cable network assumes a potential closely approaching that of the general mass of the earth (zero potential). Current, therefore, which is picked up from the earth drains back to the fault on the negative main from any point on the P.O. cable system near to it, and thereby causes concentrated, intense corrosion. The conditions are almost as though there were a direct bond between the P.O. cable network and the neutral main of the three-wire system elsewhere than at the fault.

The local depression of the ground potential in the immediate neighbourhood of a fault on a negative main will result in a flow of current from the P.O. cable to ground in this area. The P.D. measurements between a P.O. cable and earth may be quite high (possibly 50V, cable positive) close to the fault but will rapidly fall off as the distance from the fault is increased. The choice of position for the exploring earth spike is very critical as the potential gradient is so steep. The intensity of the current leaving the telephone cable sheath will be high, especially if the duct is damp, and the damage will be concentrated. This type of fault usually occurs with old mains, particularly with those insulated with bitumen and having no lead sheath.

Where, however, a fault occurs in a lead-covered impregnated paper insulated main, the leakage current initially flows from the lead sheath to the core rather than from the ground. The leakage current may soon increase, however, to the point of melting the lead sheath locally, and as the lead runs off, the current is drawn more and more from the earth. Any P.O. cable near the fault, therefore, begins to feed current into the earth and its sheath is soon damaged.

Where such a power main is in a short isolated length of iron pipe and becomes faulty, current will flow from all parts of a P.O. cable which lie near the iron pipe, and the damage will be spread over a greater length of cable : the actual perforation of the cable sheath is usually somewhat delayed.

The case of a *fault on a positive main* may be similarly studied, but the effects upon a P.O. cable are entirely different. In the vicinity of the fault, current flows into the P.O. cable and over a restricted area P.D. readings between cable and ground may be high, the ground being positive to the cable. No damage will, in ordinary circumstances, occur to the cable sheath in this area.

The current in the P.O. cable will, however, return to earth (and thence via the earth plate to the neutral of the power main) over a wide area and will not often be so concentrated at any point as to cause appreciable damage to the P.O. cable sheath. If, however, any section of the P.O. cable network passes close to the earth plates of the power system or close to any heavy iron pipe which also passes near them, the discharge of the current from the P.O. cable sheath may be relatively concentrated and in some cases be so intense as to cause local damage. It is obvious that the fault on the P.O. cable will in such circumstances be remote from the fault on the positive main and may not appear to have any connection with it.

Cyclic Variation of Resistance of Loaded Earth Electrode.

An interesting case of damage to a P.O. cable, due to leakage current to the negative conductor of a three-wire D.C. main, has actually occurred and is worthy of mention.

The two-wire service cable into a building from the negative main had been inadvertently left alive up to the service cut-outs, and these had subsequently been completely buried under a heap of rubble left after the demolition of the premises. Dust had collected in the cut-out case and moisture was finding its way in during wet weather, so that leakage occurred from earth to the live terminal. A P.O. cable in the adjacent footway broke down and, later, was found to have been perforated by concentrated electrolytic action. When the duct was being uncovered the ground was found to be hot and steaming. At this time, however, no appreciable P.D. between earth and the damaged cable sheath could be detected.

The explanation was only provided after the case had been studied further, and the chances of making a successful claim had been jeopardised. It is known from experience gained with earth plates carrying heavy currents that the flow of such currents is generally intermittent, varying from zero to full current and falling to zero again with a periodicity of some hours. The moisture in the cut-out may, therefore, be assumed to have been dried out by the heat produced at the fault to a point of complete interruption of the current, after which the slow percolation of moisture gradually re-established the circuit and the cycle was repeated. Doubtless the weather played its part and would cause the duration of the cycle to vary considerably, but the fact that the ground was still hot and steaming at a time when the leakage had ceased, no longer presented a difficulty and should not puzzle investigators in future.

A Novel Method of Surveying Boreholes

C. E. PALMER JONES†

U.D.C. 526.915

At the request of the Ministry of Fuel and Power, a method of underground surveying, using static magnetism, has been devised at short notice. The apparatus consists of a remote-indicating compass and a powerful magnet, each of which had to be designed to be inserted into a borehole only four inches in diameter. An accuracy within about two inches for distances up to the limit of 15 feet is obtainable.

The Objective.

IN December, 1949, the Post Office Engineering Research Station received an enquiry from the Ministry of Fuel and Power as to whether cable-tracing methods could be adapted, in the space of a month or so, to be usable for tracing the course of holes bored deeply in the ground.

The final objective of the Ministry is to be able to generate a continuous, copious supply of gas for use as industrial fuel by burning coal in a forced air draught where it lies in the ground. The present preliminary experiments are on a limited scale and are primarily directed to the evolution of suitable techniques of combustion control, and to economic studies. The research is being carried out at an opencast site which has been worked to the point where it is not economic to dig any further to follow the seam into the ground.

Holes four inches in diameter (after casing) were to be bored in the ground to give the effect of a U-tube with its lowest part in a coal seam. Two verticals nearly 100 ft. long were to be drilled down to intersect a hole bored almost horizontally within the coal layer, the immediate objective being to bring about accurate intersection. The scheme is illustrated in outline by Fig. 1.

† Executive Engineer, London Telecommunications Region (formerly at Research Station).

The lateral hole is certain to wander in direction and depth from the course planned for it, and the vertical holes always depart to at least some slight degree from truly vertical. Thus, quite a difficult and novel problem in surveying is presented. The approach is to assess the separation between trial vertical holes and the lateral bore in order to trace its course and to deduce where to drill to make the desired intersection. The number of trial holes must be kept to a minimum and use can be made of the barrier holes put down for safety precautions in controlling the fire to be lit in the coal mass.

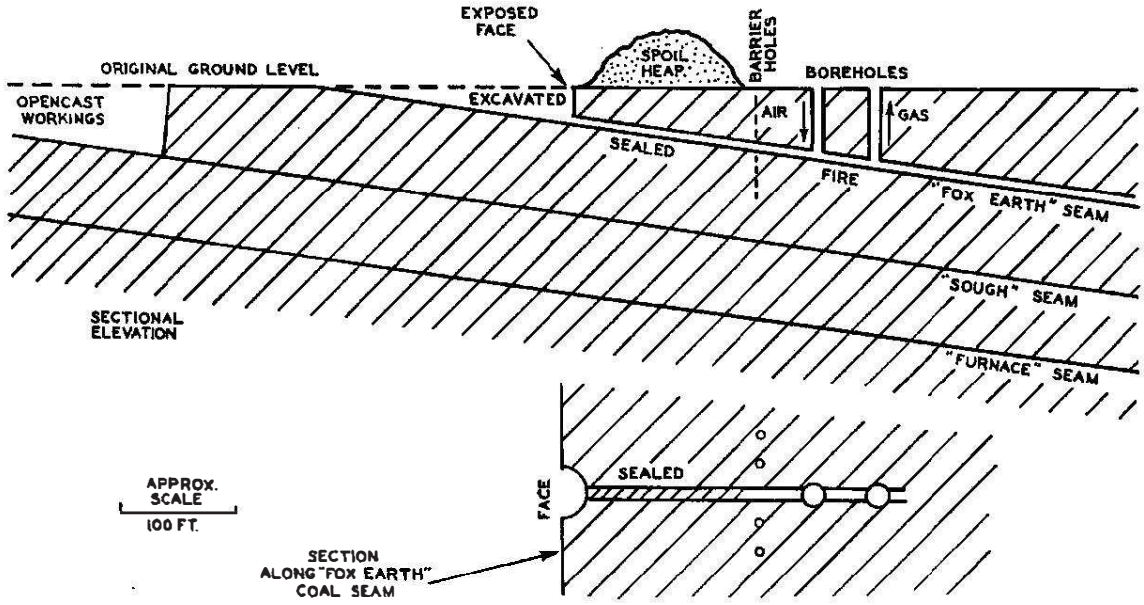


FIG. 1.—EXPLANATORY DIAGRAM OF UNDERGROUND GASIFICATION TRIALS.

Choice of Method.

The known methods of finding shallow-buried cables do not lend themselves to finding the relative positions of boreholes at full depth. However, another idea occurred and, as it appeared feasible, co-operation was promised. Static magnetism with a powerful magnet would be usable, and would have a range of a few yards. The essence of the magnetic method of finding the distance between the two deep holes is to observe the effect upon a magnetic compass at the coal-seam level in the vertical hole, while a magnet is pushed into a number of successive positions in the lateral hole.

The idea of plotting magnetic fields offered accuracy of distance and direction, simplicity in operation, with cheap, robust gear and safety for personnel—

if not for their wrist-watches! Two objections had to be considered. First, errors might arise due to magnetic minerals if such were present on the site. Second, it looked as if a large amount of effort would be necessary to carry out calibrations of the magnetic field patterns. These would have to account for the whole range of possible tilts and directions of the lateral hole in which the magnet would lie while testing.

The first objection was quickly overcome. A careful survey of the site with a prismatic compass showed that the only aberrations over a considerable area were close to the drilling rig and to a dump of steel stores. These were to be expected. Supposing there had been a minor quantity of magnetic mineral, it still might have been possible to allow for its presence, but actually mineral samples from various depths were shown to be without effect on the compass needle.

The second objection also proved not to be serious in practice. It was discovered that the magnet could be tilted several degrees from its assumed slope in the lateral hole without appreciable effect upon the reading of a compass used in the horizontal plane through the centre point of the magnetic axis of the magnet. Actual calibration work was carried out with a tilt of 15° to simulate the best forecast of field conditions at the coal mine. Again, a useful discovery was made which avoided the need for sets of calibrations for various deviations up to 20° from the expected direction (approximately E-W) of the lateral hole. Within this 40° sector at least, the average deflection, *after polarity reversal,* is always the same.

That the method would be usable had been confirmed by calculations and models to scale. These showed further that empirical calibration is very desirable.

Two alternative methods, whose merits and objections had been considered, were to use the electrical resistivity of, or the attenuation to gamma radiation offered by, the soil which intervenes between holes when distances apart are to be measured. The opportunity had been taken to make a survey of soil resistivity distribution during the preliminary visit to the site. Schemes using resistivity or any alternating electromagnetic effects suffer errors due to unpredictable reflections and variations of current distribution which occur in the skew, multi-layer system which constitutes the soil. To use radioactive isotopes as a source and a Geiger counter assembly as detector would be relatively simple, but lack of range would be a severe handicap. Only a small quantity of radio-active isotope (cobalt is preferred) can be safely handled and every foot of intervening soil reduces the count by a factor of 10^{-1}, approximately. The range of the magnetic method varies as the volume of the magnet as long as there is power available to saturate it. The sensitivity of the compass used does not affect the range, but it needs to be adequate to overcome the frictional forces in the compass so that field direction is correctly indicated.

The Requirements.

Practically all small-area geophysical surveying is based upon a selected point as origin and two natural directions, gravity and terrestrial magnetic field. For a rectangular co-ordinate system, the horizontal component of the earth's field at the origin gives Magnetic North. To this system of axes all instrumentally observed lengths and angles are referred. The P.O. technique is entirely magnetic in operation, respect having been paid to the direction of gravity in accepting the boreholes called "vertical" as truly so. At a depth of 100 ft. the out-of-vertical is not likely to exceed an inch or two, which is not enough for the assumption to produce any significant error.

The requirements in using the magnetic method are a strong enough magnet and a remote-indicating compass that will go into the four-inch holes which may well be full of water. Steel pipes casing the boreholes should be omitted in the area to be searched so as to avoid disturbance of the magnetic conditions; 10 or 12 ft. away from the magnet and compass at the nearest approaches is probably enough.

Apparatus.

To develop a suitable remote-indicating compass within the given time and size limitations was difficult, but with the assistance of a firm of experimental model engineers, production of a model designed by the P.O. specially for the purpose was achieved by mid-February, 1950, ready for use in the experiments. This "G.P.O. Remote-Indicating Compass" could not be ready for testing in January, the originally forecast month for the surveys, and therefore the possibility of realising a ready-made remote-indicating compass was earnestly explored. It was discovered that the Admiralty Compass Observatory had a fully developed instrument of considerable refinement. Nothing less than a 7-in. diameter borehole would permit its use, however, and even then quite a lot of modification would be necessary to bring the leads out at the top, to make it water-tight and capable of functioning with as long a lead as would be required for this use. The Ministry considered that the urgency justified the trouble involved and arranged to have reamers flown from Canada to widen the holes if needed. On hearing this the Admiralty Compass Observatory authorities willingly and quickly carried out the necessary alterations to suit their "A.T.M.C. Type 4" for the new project. Fig. 2 shows the complete outfit which was ready in good time. The coupling to the top was made interchangeable with the P.O. design; both were to be attached to dural tubing in 10-ft. lengths for lowering.

Before examining the details of the P.O. compass design, it may be helpful to consider what is involved in providing a magnet to produce deflections. For insertion in the lateral borehole, the complete magnet assembly is attached to the drill rods as used in boring the hole. These are 20-ft. screw-ended lengths of steel tube about $3\frac{1}{2}$ in. in diameter. The magnet assembly is 20 ft. long. Externally it is a brass tube with a rounded nose at the leading end and a screwed adapter for attachment to the drill rodding at the other end. Half the length is empty and serves to isolate the magnet from the steel rods by a sufficient distance to ensure that accuracy is not

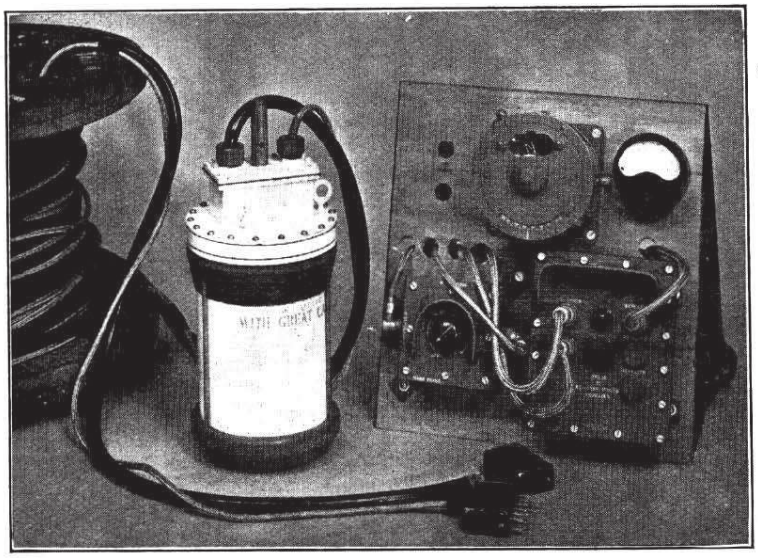


FIG. 2.—COMPLETE EQUIPMENT OF MODIFIED ADMIRALTY REMOTE-INDICATING COMPASS.

sacrificed. Inside the leading end is a 10-ft. bar of Swedish soft iron, 2 in. in diameter, on which is wound a coil of 8,500 turns spread in four layers

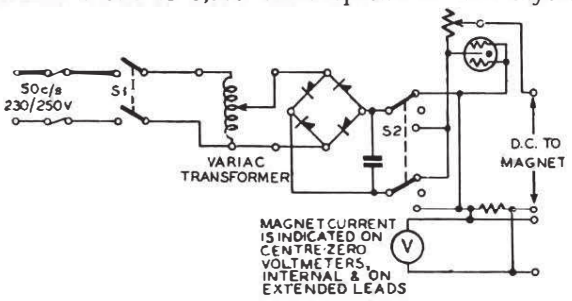


FIG. 3.—CIRCUIT DIAGRAM OF MAGNET CURRENT CONTROL PANEL.

along the whole length of the bar. In this coil one ampere is sufficient to produce saturation flux, 300,000 maxwells at the centre of the bar, and 120V are necessary to pass this current. The leads to the electro-magnet are fed through the hollow rods to connect up with the power panel designed to feed it and located at the entrance to the hole. The schematic diagram of the power panel which takes an input from public supply mains, or the equivalent from a petrol-electric set, is shown in Fig. 3. It will be seen that a gas discharge tube is used to absorb the surge which might follow a sudden change of current. Another such tube is incorporated in the magnet assembly, joined in shunt with the winding. There is a quantity of rubber and sponge-rubber inside the magnet case to cushion shocks and a wax filling to prevent ingress of water. Fig. 4 is a photograph showing the magnet assembly supported on the framework used during the calibration work; the tilt is 15°, i.e., roughly the slope of the coal seam. A theodolite compass is in use for this work, because at that time neither of the special compasses had been completed. Curves are being obtained by the engineers to indicate the successive deflections of the compass to be expected as the magnet is moved along its own axis at various distances, with checks in various directions making small angles with an East-West line. These curves (Fig. 5 indicates some typical ones) form the basis of position recognition when the underground tests are in progress. It has already been mentioned that the calibration must be undertaken with the actual magnet to be used in the field work. Calculated curves or those from models of the magnet fail to take account of the exact distribution of the field pattern around the magnet arising from the particular nature of the leakage field. A very necessary precaution in carrying out any tests which involve a change of current (including changes from zero) is to saturate the magnet with one ampere in the *reverse* direction and then to bring the current through zero up to the required value. If this is overshot, the whole of the magnetising cycle must be traversed again to come up to the required adjustment.

Fig. 6 is a photograph of the G.P.O. Remote-Indicating Compass as a complete assembly, with the partly dismantled spare one alongside. It contains a magnetised needle pivoted to swing in a horizontal plane between two jewelled bearings. Light phosphor-bronze wings are carried by the needle so as to make contact, when pressed downwards, on a circular track potentiometer. Where the ends of the winding of this potentiometer come, there is a blind spot of 3° or so, but the whole instrument can be turned

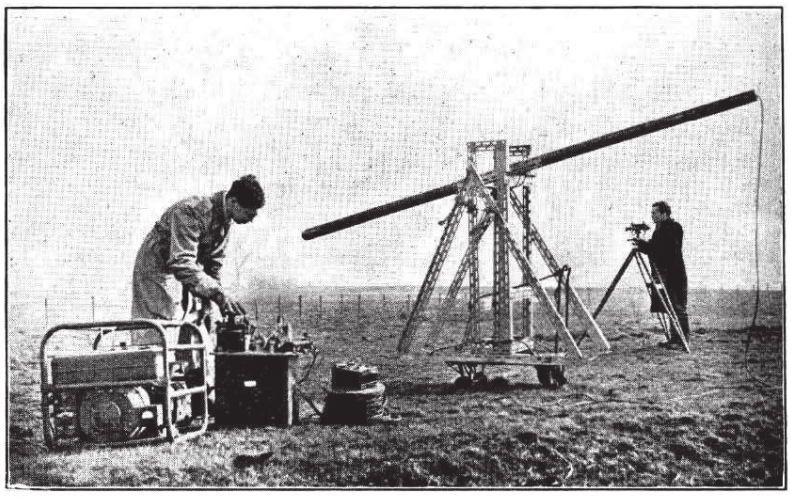


FIG. 4.—METHOD OF SUPPORTING MAGNET ASSEMBLY DURING CALIBRATION.

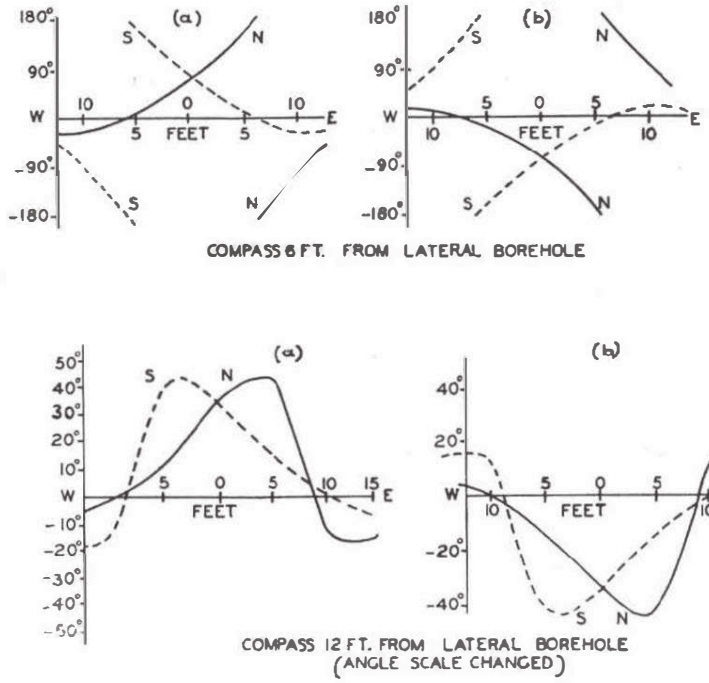


FIG. 5.—TYPICAL CURVES OF DEFLECTION *v.* LENGTH AS 10-FT. SATURATED MAGNET MOVES PAST COMPASS FROM WEST TO EAST: (*a*) WITH SOUTH POLE LEADING; (*b*) WITH NORTH POLE LEADING. CURVES S, MAGNET SOUTH OF COMPASS; CURVES N, MAGNET NORTH OF COMPASS.

Note :—These curves are shown to illustrate the forms taken by plots of Deflection *v.* Length. The full set of accurately plotted curves enables :—

1. Separating distance to be estimated roughly.
2. Sense to be decided.
3. Accurate centering of the magnet for curves of Fig. 9 to be used for precise distance determination.

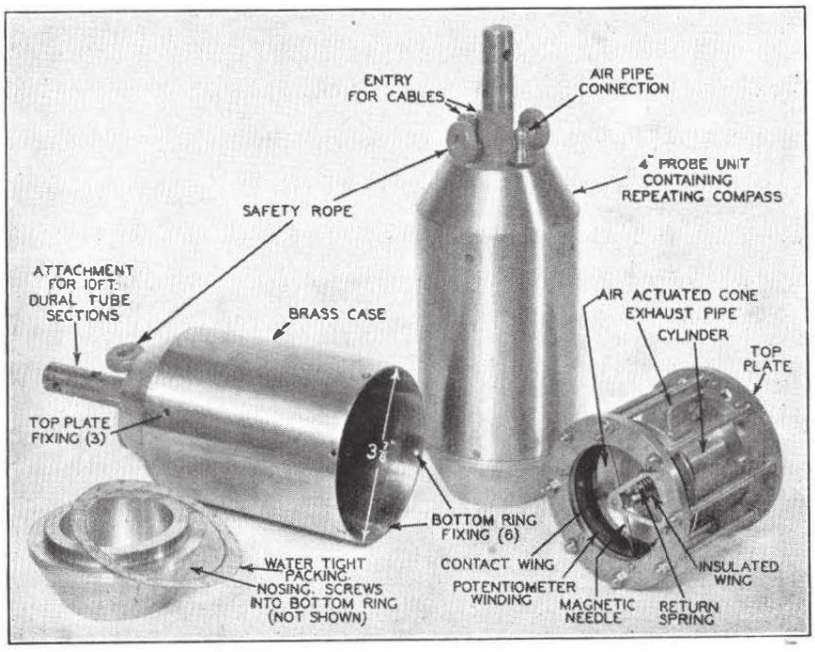


FIG. 6.—THE G.P.O. REMOTE-INDICATING COMPASS AND ITS PARTS.

by means of the supporting dural tubes to give a satisfactory starting position.

Downward pressure to clamp the magnet and establish the contact is accomplished by feeding compressed air to the unit via a pressure tube which, with the leads from the ends of the potentiometer, is led to the surface. The air forces a piston to move against a spring and in so doing brings a cone to bear down on the wings so that one of them makes contact (the other is for balance only and is insulated). Accurate balance and freedom of movement of the needle assembly are necessary and so is smooth positive motion of the piston and cone assembly. Precaution is taken against turbulence in the air surrounding the needle. A slow leak for air is provided to ensure successful repeat operations. At the surface a simple bridge circuit (Fig. 7) is manually brought into balance so that a galvanometer deflection is reduced to zero, and then the compass indication can be read directly off the dial associated with the one knob used for balancing. Any field due to the small current used in the potentiometer is not sufficient to affect the compass needle.

The Admiralty compass is self-synchronising and the repeating compass at the surface reads continuously and directly. With a suitable repeating compass the bearing is displayed to an accuracy within 10 minutes of arc, the indication being dead-beat for small changes. A battery of 24V is needed to feed 4A continuously to the motors and the electronic control panel. In contrast, the P.O. instrument requires only a few milliamps from a 6-V battery and is far less complex in construction, but it cannot claim better than 1° accuracy.

The Survey.

The procedure in carrying out a survey is first to check up that the strength of the earth's magnetic field (horizontal component) is the same at the top and bottom of the borehole. This is done by fitting a small coil on the top of the compass casing and energising

t from a battery to provide a reference field ; the compass is used in the role of magnetometer. If the strength is unchanged, it is fair assumption that the direction is also unchanged. The next step, having

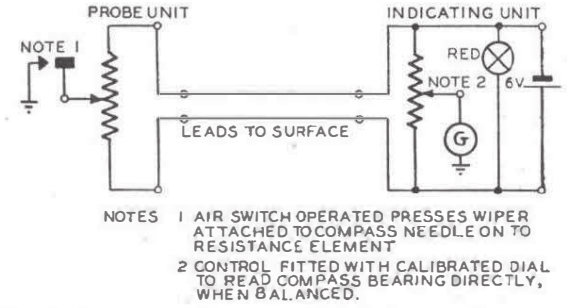

PROBE UNIT
INDICATING UNIT
NOTE 1
RED
NOTE 2
6V
LEADS TO SURFACE
G
NOTES 1 AIR SWITCH OPERATED PRESSES WIPER ATTACHED TO COMPASS NEEDLE ON TO RESISTANCE ELEMENT
2 CONTROL FITTED WITH CALIBRATED DIAL TO READ COMPASS BEARING DIRECTLY, WHEN BALANCED.

FIG. 7.—SCHEMATIC CIRCUIT OF G.P.O. REMOTE INDICATING COMPASS.

disconnected this coil, is to introduce the magnet into its borehole, after testing for polarity and applying a spot check on field strength. It is then pushed forward on rods by the drilling rig without rotating, into the lateral borehole (see Fig. 8), until it approaches the position where it will probably begin to affect the reading of the compass waiting in the vertical hole being surveyed. Then the magnet is moved on at intervals under telephone control of the party working the compass controls, that is to say, the air control cock and the balancing knob. A curve is plotted connecting the length changes of magnet position with the angular changes of compass indication. When the magnet has passed beyond the region of effect upon the compass, its polarity is reversed and it is brought out again by stages while another plot of length against angle is made. From the synumetry of these curves (which are of the type illustrated in Fig. 5) it is possible to guide the magnet to a position such that the compass lies on the horizontal right bisector of the magnet. The compass being at coal level at this stage, it is now moved up and down by small steps to confirm that an optimum reading exists and that, therefore, the compass and the magnet centre lie in the same

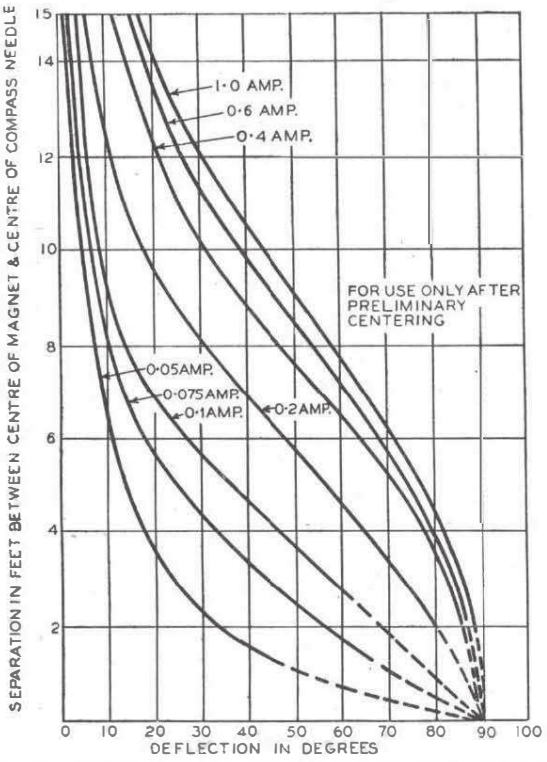


FIG. 9.—CURVES OF DISTANCE v. DEFLECTION AT SELECTED INTERVALS OF MAGNET CURRENT. DISTANCE MEASURED ON HORIZONTAL RIGHT BISECTOR OF MAGNET LYING E-W (MAGNETIC).

horizontal plane. Finally, a curve is plotted for the accurately centred arrangement to relate deflection against the current in the magnet winding using prearranged steps of current for which the calibrations have been previously plotted (see Fig. 9). The distance separating the magnet and the compass can then be estimated for each of the currents, and the (weighted) average of these yields the information which has been sought. The weighting depends upon the slope of the calibration curve at the point where the reading is taken.

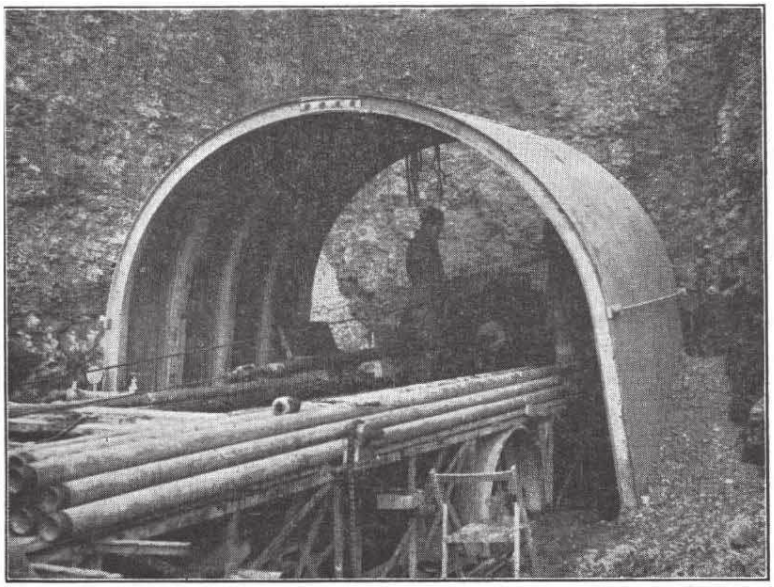


FIG. 8.—DRILLING RIG AT ENTRANCE TO LATERAL BOREHOLE.

Performance Details.

Using the technique described, an error of less than an inch was shown to be possible in an actual distance of over 13 ft. during rehearsals. Accuracy falls off over 15 ft. and also in the immediate vicinity of the magnet. Within a foot or so the forces acting on the compass needle pivots are undesirably great ; a smaller magnet is under trial for very close work, but the large one can be used if the higher

values of current are avoided at times when the compass needle is near and not clamped.

It was actually in March before the survey was required ; delays were due to various unforeseen causes, one of which was the great difficulty experienced in getting the lateral drilling reasonably straight and near the proposed position in the coal seam. The attempt which was destined to succeed was assisted by sinking the vertical holes along the track of the lateral hole so that the underground surveying could be used to keep trace of its tortuous course. Most of the vertical holes were four inches, but one was cut to eight inches in readiness to put the Admiralty compass into commission if the P.O. compass gave any trouble, but actually it did not. Due to the exigencies of their main task, the Ministry were unable to afford an opportunity to try out the larger and more refined equipment, but they have undertaken to provide an opportunity† to do so in the next phase of their experiments.

The distances actually observed were found to be 1 ft. 2 in., 3 ft. 1 in., 3 ft. 10 in. and 11 ft. 9 in. The last two proved to be out of range of some elaborate radio-active equipment tried out before the G.P.O. survey started, but it was satisfactory to note that the first two agreed with that equipment within an inch or so. If the verticals had been truly parallel to each other, the course of the lateral would have become correctly known and new verticals could have been drilled accordingly to make intersection. Actually the drilling was not quite precise, but a small explosive charge forced a clear passage between the holes.

With a jointer's tent at the top of the hole being tested, another at the entrance to the lateral hole and cover for the generator and subsidiary equipment, good weather protection was afforded and the laboratory-made gear proved quite suitable. There was some unintentional very rough handling of the magnet when and after its connector became accidentally unscrewed from the drilling rod. After first-aid repairs to the casing, connector and cabling, it continued to give good service.

Acknowledgments.

Permission to publish information contained herein is gratefully acknowledged to the Admiralty and the Ministry of Fuel and Power, as also is the hearty co-operation given by these Departments and the author's colleagues at Dollis Hill whereby this job was swiftly, resolutely and successfully tackled.

† Since this article was written the opportunity has occurred (May 1950) to use the Admiralty compass in further surveys. As expected, it performed well and was very convenient to operate. While the P.O. compass is adequate and needs no enlargement of the borehole, it is clear that, had the programme delays not occurred, the Admiralty "rescue" in January would have been most effective.

Book Review

"Vade Mecum ('The World's Radio Tubes'), 1950." P. H. Brans. P. H. Brans, Ltd., Antwerp. 508 pp. 20s.

The eighth international edition of P. H. Brans' Radio Tube Vade-Mecum, 1950, shows two major changes compared with its predecessors, in that it is now published as a single volume and the valve base data are segregated in a separate section. Otherwise previous users of this work will find the layout and classification exactly as before.

The book has for its aim the collection of the more important characteristics of all current valves produced throughout the world up to September, 1949, and includes, in addition to conventional receiving types, such items as projection tubes, accelerometers, crystal diodes and the recently introduced crystal triodes. An approximate estimate showed that the number of different types listed exceeds 10,000 and, in addition, about 1,200 different base connections are illustrated and classified.

The introduction and instructions on how to use the book are repeated in five languages, Dutch, English, French, German and Danish. The valve types are classified alphabetically and numerically in a comprehensive index that gives the following preliminary data : (*a*) manufacturer, (*b*) number of the table in which the main data are to be found, (*c*) filament voltage, (*d*) reference number of base connections and (*e*) valves having equivalent performance.

The main tabulated information is divided so that all the valves of one category are listed together in one table where they are further sub-divided according to heater or filament voltage.

The value of a valve reference book of this type is largely determined by the following four qualities : the degree to which the valve list is comprehensive, the amount of data given, the accuracy of the data and finally the facility for finding a particular item of information. In order to form an opinion on these four points, approximately 50 valve types were picked at random from current British Manufacturers' lists and consulted in the Vade Mecum. The conventional valves were all found without difficulty, but three gas-filled triodes and four types of disc-seal valve were missing. The information given was generally adequate for many purposes with, however, some important exceptions. The data on interelectrode capacitances were meagre, being confined to occasional values quoted in the remarks column, and, for some of the rectifiers, the mean anode current quoted referred only to a particular circuit without making this point clear. The data were, in general, found to be accurate and showed only minor occasional differences from the manufacturers' published information, while all the information sought was readily found once the method of classification had been mastered.

Some criticism of the presentation of the high-power valve characteristics is called for in that the relevant working conditions are not made clear. The usefulness of this section would also be enhanced by stating the type of cooling, i.e. radiation, forced-air or water cooling.

The book has, however, attempted a truly monumental task with considerable success and many workers in the sphere of telecommunications and electronics will find it a valuable and convenient reference work, particularly for those workers whose main interest lies in the servicing and installation of equipment.

K. D. B.

Power-Operated Doors

D. J. HARRIS, B.Sc.(Eng.), A.M.I.E.E.†

U.D.C. 624.028.1—83

This article is about power-operated and automatic doors used for draught exclusion in buildings and particularly in postal sorting offices, but there are many applications of power operation to doors and gates, and some of these are considered briefly.

Introduction.

A GATE or a door is useless unless it is usually closed. The chief difference between them is that a gate can only prevent free passage through an opening, whereas a door has additional uses, chief among which is exclusion of draughts. Whenever a door is opened to allow a passenger to pass through, it should be closed again immediately afterwards to prevent an unauthorised person from passing through or to exclude a draught. Unfortunately, closing the door does not help the passenger on his way, and consequently doors are often left open.

The simplest solution to the problem is the self-closing door; energy is stored in a spring when the door is pushed open and it closes automatically behind the passenger. Additional effort is needed to open the door, but the passenger does not object to this as he is saved the worry of thinking about closing it. However, this kind of door is not effective where vehicles must pass through. A vehicle cannot push its way gently enough to avoid damage to itself or the doors, or both. An ordinary door is more suitable for a vehicle, but then the driver must dismount once to open the door and a second time to close it—if he remembers. Alternatively, where there is frequent traffic, a door-keeper may be employed or the door may be left open, for if it is heavy, opening and closing by hand would be hard work.

All these difficulties can be overcome by power-operating gear for opening and closing doors or gates, and by automatic control of the operating gear in some cases.

Purposes of Power Operation.

The term "automatic doors" is sometimes used incorrectly. Power-operating gear saves the effort of opening and closing a door, and the gear may be controlled automatically, but not necessarily. An automatic door is one which opens on the approach of a passenger and closes behind him without deliberate action on his part. He is saved the trouble of thinking about opening the door and remembering to close it. Power-operated doors, on the other hand, may be controlled by some person other than the passenger. A semi-automatic door is one which requires deliberate action to open *or* close it, but which performs the other function automatically.

Besides saving labour and thought, power-operated doors may be employed as safety devices as the following examples illustrate :—

Lifts.—Time is saved in preparing to enter or leave the car. The attendant, on car switch lifts, and the passenger on automatic lifts, is saved the effort of opening and closing both landing and car gates. On automatic lifts the passengers are protected from the danger of opening the car gate while the lift is in motion.

Underground Railway power doors save the passengers the effort of opening and closing doors, and protect them from draughts and from the danger of stepping out of the train when it is in motion. The station staff are saved the trouble of checking that the doors are closed and time is saved in ensuring that all is safe before the train leaves the station. The guard has complete control.

Buses.—A door can be provided to protect the passengers from draughts and the dangers of mounting or alighting while the bus is in motion, without giving the conductor additional work in opening and closing the door at halts.

Shops.—The customer is welcomed automatically, and if he leaves carrying parcels he is saved some inconvenience.

Warehouse Gates must be controlled to prevent theft. With power gear for the gates, the gatekeeper can give close supervision to the traffic without delaying it, without effort, and with only momentary interruption of other work.

Aircraft Hangar Doors may be so large and heavy that a man could not move them without power gear to assist him.

Sorting Office Doors.

An important link in the chain of transport of mails is the transfer of bags of mail between sorting offices and railway station platforms or vehicle-loading bays. At major sorting offices, where cost and space permit, bag conveyors are installed for this purpose, but at many offices it is necessary to carry the bags on some form of truck. Consequently, at busy offices there is a continual traffic of trucks into and out of the sorting office and, unless special arrangements are made to prevent draughts from the doorways, great discomfort may be caused to the staff working in the office, not only directly from the draught but indirectly from reduction in room temperature.

The usual arrangement for reduction of draughts in Post Offices, as in other large buildings, is to provide self-closing doors. These are effective when used by pedestrians as the effort required to push the door open, though not excessive, is sufficient to ensure that it will not be held open longer than necessary. To improve draught reduction, two doors are often fitted with a short lobby between them. The pedestrian pushes one door open and that closes behind him before he has time to reach the second door and open that. Thus, the lobby provides a partial air lock to prevent through draughts. The only reasonable way to pass through such doors with a hand cart or an electric truck is to fix the doors open, thereby vitiating the draught-excluding system. But if the doors are power operated, they can be equally efficient for pedestrians or trucks.

† Engineer, Power Branch, E.-in-C.'s Office.

Power Operation of Doors

The door itself may be of the sliding or the swing type, or may perhaps rotate. The design selected depends primarily on the location and purpose, but is affected to some degree by the power-operating gear. Six driving linkages are shown in outline in Fig. 1. The

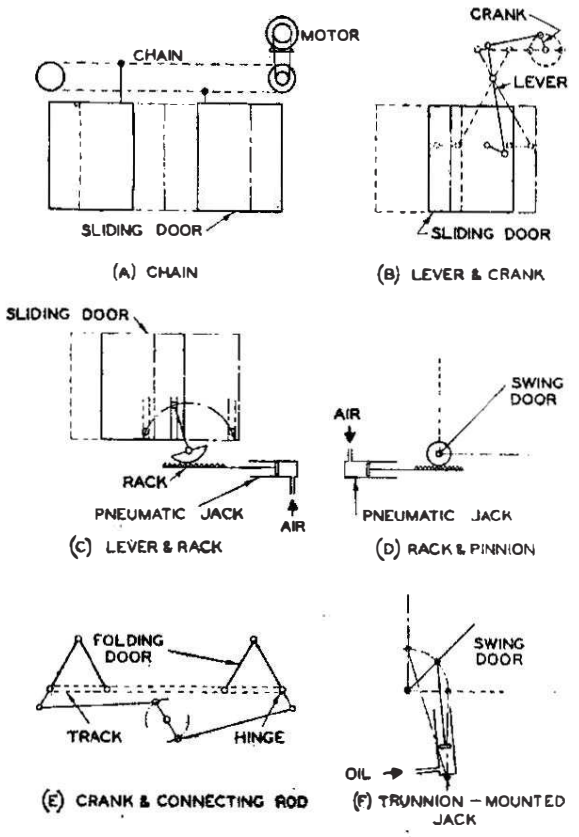


Fig. 1.—Driving Linkages for Power-Operated Doors.

overhead chain drive shown at (*A*) is suitable for large sliding doors or gates. A single door may be driven or bi-parting doors, as illustrated.

The linkage for a sliding door, shown at (*B*), is commonly used on lifts but is suitable only for narrow doorways, and at (*C*) is shown a similar scheme as used on the Underground Railways. Both these have the advantage that the velocity of the door at the limits of travel is zero, so that it opens and closes without slamming. Linkages (*D*) and (*F*) have been applied to swing doors, and that at (*E*) is for small folding doors as sometimes used on buses. The trunnion-mounted hydraulic jack, shown at (*F*), has the advantage of giving a maximum torque at starting to open the door and a minimum when the door is fully open so that slamming is not severe.

In most applications the driving gear should yield if the door meets resistance, but continue to move the door when the obstruction is withdrawn. Alternatively an automatic device may be provided to reopen the door if it meets resistance in closing. Some provision must be made to prevent injury to a person struck or trapped by the door, and if this device is self-resetting the door will not be left partially open after the device has operated.

This consideration makes pneumatic operation suitable, as an air receiver in the supply system allows the door to be stopped without overloading the driving motor. Pneumatic door operation is used on railway trains and buses where the air receiver may be charged from the traction motive power.

In buildings, an electric motor must usually be used to drive the operating gear, and as an air compressor is rather noisy a mechanical or hydraulic linkage may be preferable. A solenoid of the power required would be inefficient, but electro-hydraulic thrustors have been employed instead of motors. If a motor drives a mechanical linkage directly, a clutch or spring must be included to allow the door to yield without stalling the motor, but the motor must be stopped at the limits of travel, and each time it starts time is wasted in running up to full speed.

On the other hand, a hydraulic linkage can include an accumulator to keep the fluid pressure within limits, and if this accumulator is large enough it may be used to supply fluid to the system for several operations of the door. The driving motor is then used to pump up the accumulator only when the pressure reaches the lower limit, and full power is always available immediately to start driving the door open.

Sliding Doors and Gates.

The simplest mechanism is that required for a sliding door in a building. The door is hung on an overhead track and driven horizontally by a continuous chain in the manner shown in Fig. 1 (*A*), one chain sprocket wheel being driven by an electric motor through a clutch. When the motor is energised, the chain drives the door along the track until, when it is fully open, a limit switch is operated by a ramp on the door to disconnect or reverse the motor. To prevent slamming, shock absorbers and buffers are fitted at both limits of travel.

Space is not always available for a sliding door to open into, and collapsible shutter gates may then be used. These have the advantage over sliding doors that since the whole gate does not move at the driving velocity the momentum is less, so that shock absorbers are not necessary and a collision is less likely to cause damage. The method of drive is similar, but as an alternative to a clutch the gates may be allowed to stop by detaching the driven picket from the chain. The leading picket is hinged on the second picket, so that when it meets an obstruction it rises and unhooks itself from the driving chain which continues to move, leaving the gate stationary. This safety device is not self-restoring and the gates must be closed by hand to reconnect the drive.

Some power-driven sliding doors, particularly those on lifts, are made to reopen automatically should they meet an obstruction when closing. A simple control for this consists of a soft rubber nosing on the leading edge of the door, containing an electric contactor. When the rubber is compressed, the contacts are made and energise the control circuit to reverse the door.

Another refinement provided with Underground Railway doors allows them to be forced open a few

inches to permit a person who has caught his arm in the door to remove it. The short movement required is controlled by a spring on the door driving lever.

Sliding doors are usually awkward to open and close by hand, so that swing doors are preferable if it is necessary to use the doors when the driving gear is out of service for maintenance.

Swing Doors.

A successful mechanical linkage for swing doors is shown in Fig. **2**. The doors themselves are of the common two-leaf pattern arranged to swing open in one direction only, and the operating gear is mounted above the door lintel. An electric motor drives a large cam through a reduction gear; the cam follower drives a lever which twists two powerful springs mounted parallel with the lintel, and these drive two operating levers which open the leaves of the door. The purpose of the springs is to prevent damage should the doors open against an obstruction. When the doors are fully open, a limit switch attached to the cam shaft stops the driving motor by switching it off and applying an electro-magnetic brake which holds the doors in the open position. After a predetermined time interval, the brake is released and the motor drives the cam a little further in the same direction to its starting position where the linkage is released. Separate spring closers of the conventional pattern close the doors.

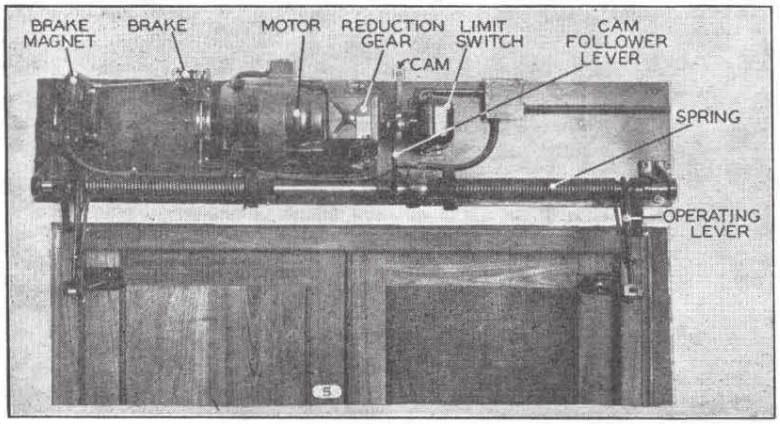


FIG. 2.—ELECTRO-MECHANICAL OPENING MECHANISM FOR SWING DOORS.

A modern equipment is shown in Fig. **3**. This employs the type of hydraulic component developed during the war for the servo controls of aircraft. Each leaf of the door is moved by a hydraulic jack (Fig. **4**). The jack cylinder is mounted on trunnions on the door lintel, and the piston acts on the top of the door near the hinge, as shown in Fig. **1** (*F*). Referring to Fig. **3** and the hydraulic circuit diagram shown in Fig. **5**, oil under pressure is applied to the piston rod

FIG. 3.—HYDRAULIC POWER-OPERATED DOOR.

(A) Projector Lamp, (B) Oil Reservoir, (C) Pressure Switch, (D) Accumulator, (E) Rectifier for Control Valve Solenoid, (F) Control Valve, (G) Equalising Valve, (H) Jack, (J) Compressed Air for Accumulator, (K) Switch, (L) Pump, (M) Photo Cell Relay Equipment, (N) Photo-Electric Cell.

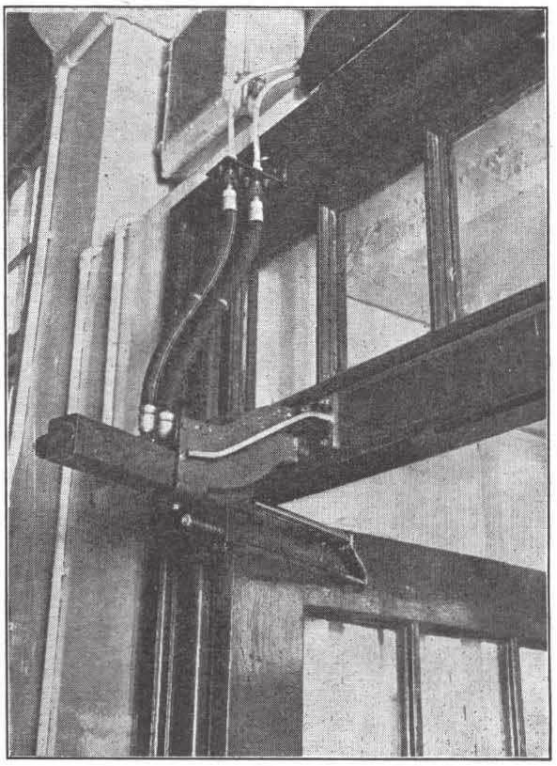


FIG. 4.—HYDRAULIC JACK FOR OPENING SWING DOOR.

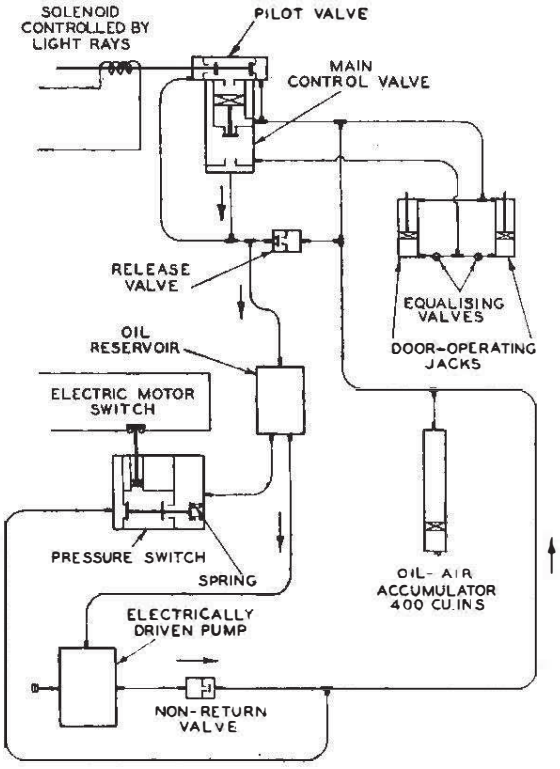


FIG. 5.—DIAGRAM OF HYDRAULIC CIRCUIT FOR POWER-OPERATED DOOR.

side of the jack pistons to hold the doors closed. To open the doors, oil under pressure is applied to the other side of the pistons as well. The opening thrust is caused by the difference in area of the two sides of the piston due to the size of the piston rod. Oil is supplied under pressure from the accumulator and is led to the jacks via the solenoid-controlled valve. Operation of this valve opens the doors immediately, even if they were closing. Each time the doors are closed, oil is discharged from the accumulator to the reservoir and the pressure in the system falls. The pressure switch is arranged to keep the oil pressure within the working limits. When the lower limit is reached, the switch operates to start an electric motor which drives the pump to re-charge the accumulator from the reservoir. When the higher pressure is reached, the switch disconnects the motor. The working pressure range is between about 350 and 250 lb. per sq. in., and the accumulator capacity is sufficient to operate the doors for 10 cycles of opening and closing. The accumulator is charged with oil against air pressure, and the lower pressure limit is set by charging the accumulator with compressed air from a cylinder. An air pressure gauge indicates the instantaneous working pressure.

When opening or closing under power, the doors can be stopped by a man without injury to himself or damage to the equipment, and if the power system is switched off the doors may be pulled or pushed open in the same way as ordinary swing doors, the jacks acting as self-closers. Equipment of this type may be applied to an existing hinged door so long as the door hinges and lintel are sufficiently strong to withstand the considerable stresses imposed by the jacks.

METHODS OF CONTROL

Deliberate Control.

Remote operation is necessary whether the door is controlled by the passenger or by a doorkeeper. The passenger should be provided with a control in his pathway towards the door and at a sufficient distance from it to allow the door to open before he reaches it. The doorkeeper requires a control in the position where he is stationed to keep the doors under observation. For instance, the guard on an Underground train has his door controller in his compartment where he can reach it as he watches the passengers from his private doorway.

Push-buttons, requiring only momentary action, are suitable in conjunction with an electrical control circuit to initiate the door action. Passenger-operated doors need one control in each lane of approach and if there is no wall conveniently placed on which to mount a push-button, it may be set in the floor or a pull-switch mounted on the ceiling with a hanging chain to operate it. If the doors are not self-closing, additional controls for closing them must be placed in each lane of departure from the doorway.

The push-button contacts are made to control a self-locking relay which energises the opening gear, and in Fig. 6 are shown the control relays and contactors for a sliding shutter gate. In this example, the relay energises the driving motor contactor and limit

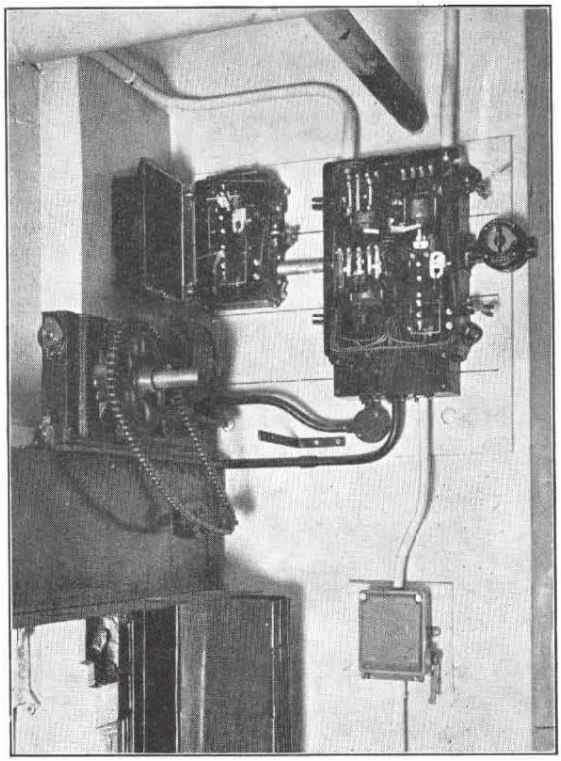


FIG. 6.—CONTROL GEAR FOR POWER-OPERATED SHUTTER-GATE.

switches, operated by the gates, release the contactor at the limits of travel. Alternative push-button closing and automatic closing circuits are provided and one of the two eddy current time-delay relays, seen in the picture, times the interval between opening and commencement of closing of the door. There is a second timing relay because the push-button stations are at different distances from the door, and when the more distant "open" button is pressed, the door does not open until the passenger has approached nearer to it.

Push-button control circuits consume no energy when the doors are closed and are very simple to maintain. For this second reason alone, they may be preferred to the more delicate equipment required for automatic control. In general, automatic closing is better than passenger-controlled closing as the passenger may forget to press the closing button.

Automatic Control.

Photo-electric cells or vehicle-actuated pads, of the type used for traffic signals, can be used to control draught-excluding doors automatically. Pads are more robust than photo-cells and are suitable for vehicles, but for a pedestrian they are not automatic as he may step over instead of on the pad. The vehicle pad, or the light ray shining to energise the photo-cell, is placed where it must be run over or intercepted by the passenger and at a sufficient distance from the door to allow it to open in good time. Closing of the door can be controlled by another pad or light ray on the far side of the door, or by a timing relay. Thus, the maximum draught exclusion is ensured and the passengers proceed as though there were no door in the doorway.

For postal sorting offices, where traffic consists of a mixture of pedestrians and trucks, light rays are more suitable than pads, but the light ray projector must be placed where it will remain lined up on the cell, and both projector and cell must be protected from impact.

The doors shown in Fig. **3** are light-ray controlled, and a projector lamp is shown mounted on the ceiling and shining on a photo-cell which is under a glass plate in the floor. The cell is connected electrically in the grid circuit of a triode thermionic valve biased beyond its cut-off. Interception of the light ray causes the photocell resistance to rise, which neutralises the valve grid bias allowing anode current to flow. The cell relay is connected in the anode circuit, and this energises another valve circuit. The second triode, biased beyond its cut-off, has a resistance-capacitance time delay in the grid circuit. The cell relay makes a contact to neutralise the grid bias, allowing anode current to flow and energise the main relay in the anode circuit. One contact of this relay is connected in the door driving circuit and starts the doors opening. The main relay remains energised until the timing condenser has discharged through its resistance, when the valve grid cuts off the anode current and the main relay is released. Momentary interception of the light ray is sufficient to re-energise the time delay and main relay, so that a continuous stream of passengers will hold the door open indefinitely.

There is a small continuous energy consumption associated with light ray equipment, chiefly for the supply of the projector lamps, and, as these lamps are lit continuously, frequent replacements are required.

LAYOUT OF DOOR-OPENING EQUIPMENT IN SORTING OFFICES

Limitations of space in existing buildings usually prevent the installation of a simple system of fully automatic doors, and the best use of available equipment presents a number of problems.

Three or four seconds is needed to open an average door without unreasonable noise or shock so that an actuating light ray must be placed several yards from the door to allow approaching traffic to continue in motion after interception of the ray and while the door opens. Where mechanical vehicles and pedestrians use the door, the speed of approach will vary from about 1 m.p.h. for a man pushing a handcart to about 5 m.p.h. for an electric truck. A compromise must then be reached in siting the rays and setting the time-delay relays to allow each traffic item to pass through the doorway with the minimum delay and without holding the door open longer than necessary.

A simple layout is shown in Fig. **7**; the door leads

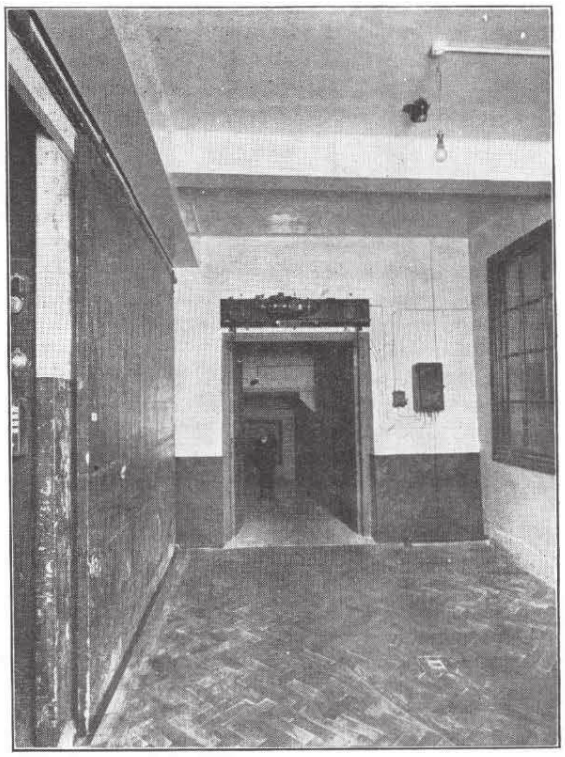


FIG. 7.—POWER-OPERATED DOOR WITH TWO LIGHT RAYS.

from a lobby outside a station sorting office into a subway under the railway lines, and pedestrians and handcarts are the only traffic. One light ray in the lobby and another in the subway shine vertically in the track of approaching traffic, and where they may be avoided by traffic which has passed through the doorway. If the second ray is not avoided, the door is reopened just as it would normally commence to

close. This difficulty may be overcome, where the approaches to a two-way doorway are narrow, by placing two light rays close together and arranging their relay circuits so that if light ray A, farthest from the door, is intercepted first the door opens, but if light ray B, nearer the door, is intercepted first it cuts A out of circuit for long enough to allow the passenger to intercept A without opening the door.

Referring again to Fig. 3, the ray in the foreground is in the sorting office and liable to be intercepted by traffic which may pass across the doorway without intending to pass through; thus, the door may be opened unnecessarily. This can be prevented only by placing a barrier on each side of the ray so that it can be intercepted only by traffic approaching directly towards the door. Such a barrier would restrict manœuvring space in the sorting office, and for this reason push-button control is sometimes preferred. A truck leaving the sorting office may commence its journey from a point near the door, in which case operation of a push-button at that point would not delay the driver. But a push-button has the disadvantage that it can make no allowance for the length of a vehicle; the associated timing relay for closing the door times from the instant that the button is released by the passenger's hand or foot, whereas with a light ray the timing relay times from the instant that the ray is released by the back of the vehicle. Thus, with a light ray the time that the door is held open is automatically adjusted to the length and speed of the vehicle, and this is of some importance where an electric tractor towing several trailers uses the same door as individual pedestrians.

With the photo-electric cell placed under a glass plate in the floor, as shown in Figs. 3 and 7, the light ray may be obscured by a piece of litter, accumulated dust or even by scratches on the glass, and the door will open and stay open incorrectly unless the glass plate is kept clear and clean, and replaced at regular intervals.

A more satisfactory layout would have separate power doors, one for an entrance and one for an exit, controlled by horizontal light rays, as shown in Fig. 8. Such an arrangement, however, uses more space and does not completely exclude draughts from the office. For complete draught exclusion, it would be necessary to have each lobby with a door at each end arranged so that one is closed when the other is open. The lobby must be long enough to accommodate the largest vehicle and also to allow it to remain in motion while one door closes before the other opens. The minimum lobby length to permit a tractor and trailer measuring 17 ft. overall to travel through at three miles per hour uninterrupted would be 43 ft. and the controlling light ray would be 13 ft. away outside the door, so that the overall length of the whole arrangement would be 69 ft. At very few offices could so much space be made available.

Where there is a short corridor on each side of the door and one-way traffic is arranged, as in Fig. 8, the light rays may be placed horizontally. This ensures that the passenger cannot fail to intercept the ray and the photo-electric cell is less likely to become obscured. The ray must shine at a low level, so that it will be intercepted by the wheels of a truck which might otherwise pass under it. In this position the projector lamps and photo-cells will be reached easily for maintenance, but must be protected from impact and from rain water if placed in the open.

Fig. 9 shows two power doors with a lobby between them. A long bridge happens to be placed outside the sorting office door with the lobby on it, but the doorway is not wide enough to allow traffic to pass in both

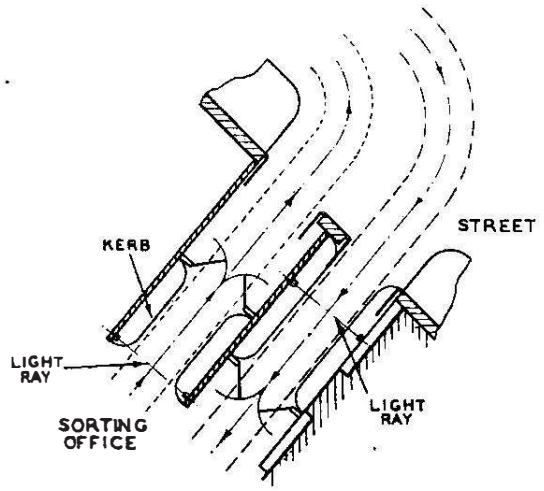


FIG. 8.—A LAYOUT OF POWER-OPERATED DOORS WITH SEPARATE DOORS FOR EACH DIRECTION OF TRAFFIC.

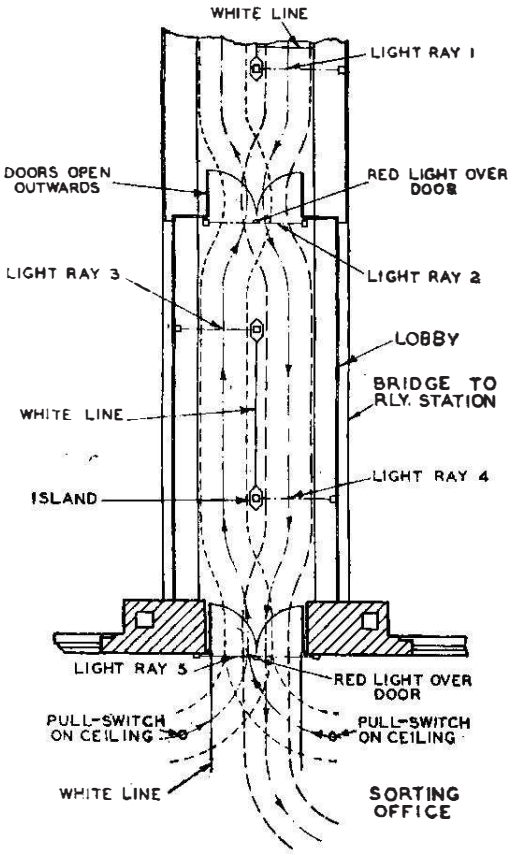


FIG. 9.—A LAYOUT OF POWER-OPERATED DOORS WITH AN AIR-LOCK.

directions at once. Separate exit and entrance lobbies could not be provided, therefore, and incoming and outgoing traffic must take turns through the one lobby. This makes a signalling system necessary to indicate to outgoing traffic when incoming traffic is approaching in the lobby and vice versa. The red lights shown in the drawing over each doorway give these signals and are controlled automatically by the photo-cells. Five rays and photo-cells and two pull switches control the doors, pull switches being chosen instead of light rays in the office for the reason mentioned earlier. For incoming traffic, light rays **1** and **4** open the outer and inner doors respectively, and light ray **3** opens the outer door for outgoing traffic. Rays **2** and **5** are to prevent the doors from closing on a vehicle delayed for any reason in the doorway and to ensure that the door closes as soon as the vehicle is clear of the ray. Both doors open outwards only, in order that winds shall tend to keep them closed.

Post Office Installations

The first installation was made at Redhill Station Sorting Office in 1935, and the whole equipment remains in service at the present time. It consists of driving gear, as shown in Fig. **2**, for two double-swing doors controlled by light rays, and one of these doors with its projector lamps is shown in Fig. **7**. The other door is similar and leads from the sorting office on the right into the lobby from which the photograph was taken. The postman seen in the picture is approaching from the railway subway and entering the lobby. On the left may be seen an entrance to a lift to the station platform and a manually operated sliding door for closing it. When the sliding door is closed the automatic doors are effective in excluding draughts from the sorting office, but when the lift is in use the lobby no longer provides an air lock. Also the traffic lanes between the three doorways overlap so that sometimes one of the light rays in the lobby is intercepted by traffic which does not intend to pass through the associated door which is then opened unnecessarily. In spite of these difficulties, the installation has given useful service for many years.

In 1939 and 1940 several installations were made using hydraulic equipment of an unusual pattern for swing doors. Each door leaf was mounted on pivot hinges in the lintel and floor, and the lower pivot was attached to a rectangular vane below the floor, enclosed in a chamber shaped as a segment of a cylinder. Oil under pressure was introduced into the chamber on one side of the vane to revolve it in the chamber and so open the door. Many faults occurred, chief among which was leakage of the operating oil, due to the difficulty of providing an adequate seal between the edges of the vane and the inner surface of the chamber. Due to difficulty in obtaining spare parts during the war, the equipment was taken out of service, but one at Birmingham H.P.O. has since been restored and the associated light ray equipment has been modified to permit interruption of the light rays by traffic from either direction without incorrect opening of the doors.

In 1949, two new installations were made at Leicester and Woking Station Sorting Offices using hydraulic equipment especially developed from the type of equipment used for aircraft servo-mechanisms. Fig. **3** shows the Leicester door which is described earlier, and the Woking equipment is similar but push-button controlled.

An automatic sliding door was installed at Reading H.P.O. in 1937, and in 1949 a pair of sliding shutter gates was added. Fig. **6** shows the driving and control gear for these gates, which are used in conjunction with the older door by electric trucks and trailers travelling between the H.P.O. and the railway station.

All recent installations are for single doors excluding lobbies as, in most cases, space would not permit a more elaborate arrangement, but proposals for new installations include the schemes shown in Figs. **8** and **9**.

Conclusion.

Power-operating gear for a sorting office door makes it possible to move mail-laden trolleys and electric trucks through the doorway without delay, inconvenience to the postal staff or damage to the door and while restricting draughts through the doorway to the minimum. Clear space is necessary on each side of the door, and for complete draught exclusion a long lobby with doors at each end is essential. Separate entrance and exit doorways are desirable to allow a free flow of traffic and permit the use of simple control equipment.

Book Review

"Telecommunications and Equipment in Germany During the Period 1939-1945." (British Intelligence Objectives Sub-Committee Surveys Report No. 29.) His Majesty's Stationery Office, 1950. 55 pp. 1s. 8d. (post free).

This survey has been prepared by a number of expert officers of the Engineering Department of the Post Office from studies of the mass of British, Combined and Joint Intelligence Objective Reports and Field Intelligence Agency reports which have already been published separately by H.M.S.O.

Lists of these reports are included in the survey which has therefore an important value for permanent reference.

The report itself includes sections on Research, Transmission, Exchange Equipment, Telegraphs, Subscribers' Apparatus, Power and Radio and these make easy and interesting reading. Where appropriate, comparisons of policy and techniques with British practice are made, including some interesting comments on subscriber-dialling. Although there are many items and advances mentioned which obviously warrant study in detail, it seems clear that war-time difficulties of dispersal and shortages of materials and manpower caused telecommunication development on the whole to mark time and lose ground relatively to the Allies.

Published at a nominal price, this report is in general a valuable contribution to the literature and history of the telecommunications industry and in particular a useful bibliography of papers describing German war-time techniques and developments.

L. H. H.

Edinburgh Conversion from Non-Director to Director

W. V. McWALTER†

U.D.C. 621.395.34

Over a period of approximately 12 years, the Edinburgh telephone system is to be completely converted from non-director to director working. An auto-to-auto transfer of this magnitude raises many complex problems since disturbance to subscribers must be kept to a minimum over the whole of the period. This article outlines the conversion plans and exchange programme involved and gives details of the first stage which has been completed by the opening of the George Street, 7,000-line director exchange.

Introduction.

AT 1.15 p.m. on 25th March, 1950, a 7,000-line director exchange (George Street) was cut into the Edinburgh local telephone network, and with it came the introduction of director code dialling by non-director subscribers. This was a key point in the first conversion in the country of a complete non-director area to director working.

In 1945, the area was served by 13 exchanges, using a linked numbering scheme within the five-digit range, and had a working multiple of 42,400. Development figures for 1955 required a multiple of 63,700. With accommodation and spare numbers seriously inadequate, discussions, which had been interrupted by the war, were resumed as a matter of extreme urgency. Within a few weeks plans were prepared and approved in principle for the complete conversion, over a period of approximately 12 years, from Siemens 16 (S.16) to director equipment.

The Conversion Plan.

The plan was based on the principle that subscribers should have the simplest possible inter-dialling arrangement and should not be inconvenienced by more than one number change throughout the whole of the conversion period. It provided for the adoption of a scheme which entailed only one arbitrary code (21). This would be used by all director subscribers when dialling a five-digit (non-director) number and, along with the first digit of the five-digit number, would form the routing code from the director exchange to the 2nd selector in the S.16 network. For calls that would be routed via the S.16 main exchange, the last routing digit, being the first of the five-digit number, would be repeated into the 1st selector of the S.16 main exchange. All S.16 subscribers would dial either the five-digit number, or the director code and four-digit number shown in the directory.

The agreed scheme required the provision of director type dial number plates on all dials in the area. It also required that the route of the numerical equivalent of the director codes used should be free in the S.16 network so that the 3rd selector level chosen by the first three letters of the director exchange name could be routed to 1st numerical selectors in the director exchange.

Fortunately, Post Office accommodation in George Street, in close proximity to the main exchange, could be made available for equipment. During the war, the floor had been reinforced to make the basement an air raid shelter for the exchange staff and therefore had the strength necessary for automatic exchange equipment. While the premises were not ideal for the purpose it was decided to install a director exchange to the maximum capacity of the ground floor and to use this, by transferring subscribers from the existing system to clear essential space in the S.16 main exchange and to free the numerical equivalent of the director codes of the most urgently required director exchanges.

The number of 10 ft. 6 in. equipment racks that could be installed on the ground floor of the George Street building was decided, and from this the size of the director multiple that could be provided was determined. It was estimated that 7,000 multiple and the necessary calling and intermediate equipment could be accommodated. When the capacity of the accommodation with the clear height necessary for equipment had been decided, ways and means of providing power, intermediate distribution frames and all other miscellaneous requirements were devised.

In addition to the accommodation problem in the main exchange area, several satellite exchanges were nearing exhaustion. A review of the satellite areas adjoining the main area indicated the need for additional exchanges to reduce each exchange area to within the 10,000 multiple capacity of a director exchange. Three additional exchanges appeared to be necessary and the areas concerned are shown in Fig. 1 as F, D, and P, superimposed on the 1945 exchange area map. This proposal entailed three new buildings, but the prospect of obtaining these was so poor that it was decided two must suffice for a number of years, the third to be built later. Names for the two new exchanges were chosen (Dean and Fountainbridge), and the areas they would serve were defined. Both would take in parts of the existing main exchange area.

Since one purpose of the 7,000-line director exchange in George Street was to free accommodation and director code levels in the existing main exchange, it followed that blocks of equipment had to be made spare and that the numbers to be transferred would have to be in numerical sequence, not chosen on a geographical basis. To meet the condition that there would be not more than one number change for each subscriber throughout the conversion period, the blocks of numbers to be transferred were divided into three groups according to geographical location and allocated numbers in the George Street director exchange which they will retain when ultimately transferred to the new exchanges, Dean, Fountainbridge and Central. The main exchange area, meantime, would take the name Central for director

†Engineer, Design Group, Engineering Branch, Scotland.

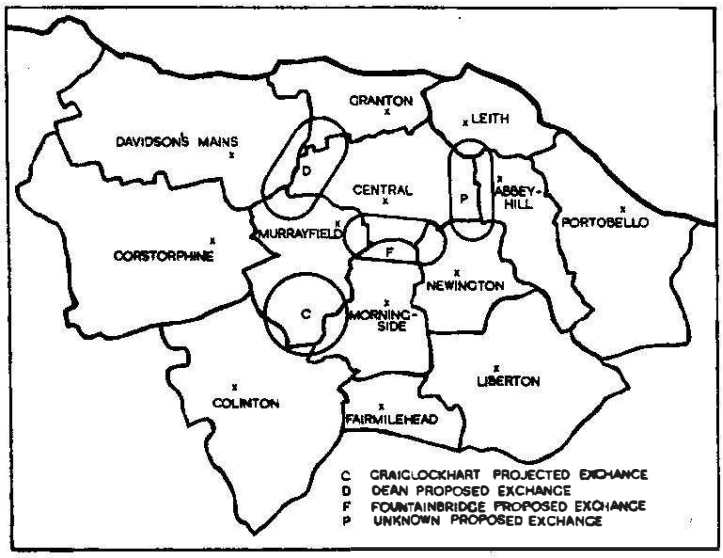


FIG. 1.—EDINBURGH MULTI-OFFICE AREA.

subscribers. The cut-in of the George Street director exchange therefore brought into use three new exchange names; CENtral, DEAn and FOUntainbridge, the latter two working as hypothetical exchanges on CENtral.

A notable point is that while it would have been very desirable in many respects to have had a new exchange in a new building, it would not have served the purpose which this three-name exchange has served, as it would have been so remote from the main exchange that it would have been necessary to transfer on a strictly geographical location basis. This would have made small groups of numbers spare, not blocks of equipment or director code levels.

While the discussions which culminated in the decision to convert to director were proceeding, plans for the installation of S.16 equipment at Craiglockhart, a new satellite exchange area, were going ahead (circle C, Fig. 1). The S.16 equipment had been manufactured before the war and stored, and the building for it had also been completed before the war. The decision to convert Edinburgh to director working, however, made it desirable to revise the plans for this particular exchange. As it was required for the spring of 1946, it was agreed that director equipment, manufactured before the war and stored in Glasgow, should be used to equip Craiglockhart as the first director exchange in Edinburgh. It was obviously impossible to introduce the agreed dialling scheme in the time available and an arbitrary two-digit code (70) was accepted as the route from S.16 to Craiglockhart director. The director installation was duly completed by the A. T. & E. Co., and the S.16 equipment which was originally intended for Craiglockhart was used to extend other S.16 exchanges in the area.

For Fairmilehead, an immediate pre-war S.16 exchange, an order for the first extension had been placed. This being a comparatively new exchange, a fair amount of spare space was available, and draft layouts showed that sufficient director equipment to replace the existing equipment and provide for the immediate future needs could be installed instead of extending the S.16 equipment. Immediate steps were therefore taken to install director equipment and again an arbitrary two-digit code (59) was accepted for routing from the S.16 network.

Further, to meet development it was necessary to equip three relief manual exchanges in the area. The names for these exchanges were chosen to have the first three letters corresponding to available numerical codes so that in the pre-director dialling period access would be by numerical code which could be changed to three-letter code dialling without any route changes.

Thus, prior to the opening of the George Street director exchange, two two-digit and three three-digit codes were in use and all were replaced by the first three letters of the exchange names simultaneously with the introduction of the new exchange. The objective dialling scheme has thus been achieved.

THE GEORGE STREET TRANSFER.

George Street Exchange.

Some 5,200 subscribers were transferred from the old main exchange to the new George Street exchange, installed by the G.E.C. Although the amount of work involved was small by comparison with many other transfer schemes which have been put through in the past, some aspects warrant special mention.

The basement of the new exchange consists of a number of small rooms, the dividing walls being also main supporting walls which could not be removed. In the largest room, which has a maximum height of 10 ft. 10 in., with only 9 ft. under beams, and is 11 ft. 9 in. wide, the subscribers' intermediate distribution frame of 37 verticals occupies the full length with a clearance of 2 ft. at one end and 4 ft. 3 in. at the other. In spite of the very restricted space, the cabling is a fine example of the art, and the installer is to be congratulated on the great ingenuity displayed.

The line side of the I.D.F. is cabled to a locally-made protector frame located in a smaller room, separated from the I.D.F. room by a passage and stairway. The protector frame is equipped with normal protectors on both sides and the line side of the protectors is cabled to the exchange side of the main distribution frame serving the S.16 main exchange, where the cabling terminates on tag blocks, 600 circuits per vertical. Between the two frames paper insulated cables, all 200-pair, were laid across a public lane, 21 ft. wide. This method was adopted to make use of the present terminations of subscribers' cables and to conserve space on the exchange side of the M.D.F.

The junction I.D.F. is located near the protector frame, while test jack frames and ringing machines are in another room in the basement. Power is supplied from the power room in the old exchange,

an existing 50V supply from the main 60V plant being increased by the installation of additional machines.

Siemens 16 *Main Exchange* (*Rose Street*).

The S.16 main exchange is located on two floors of a building which was first used as a C.B. manual exchange and District Manager's office, and is now used for the joint trunk exchange and the repeater station as well as the automatic exchange. The ground floor has the necessary height for 10-ft. racks, but on the second floor there is height only for 8-ft. racks.

The building contains equipment for 13,300 lines, junctions to and from 12 satellite exchanges, and the terminal equipment for a complete group and zone network, and free space is severely limited. By rearrangement and concentration of switches, space was made available for the 400 leg-to-loop relay sets required on the junctions to director exchanges, but it was not possible to find space to install racks for loop-to-leg relay sets and incoming selectors required on junctions from director exchanges. Therefore, an alternative method of termination was devised.

In the S.16 main exchange the subscribers' 1st selector accepts loop impulses and, as 5,200 subscribers were to be transferred, a considerable amount of originating traffic would be withdrawn. An examination of the number range to be transferred and the divisions affected by the withdrawal of originating traffic indicated that the 1st selectors serving three full divisions and one partly-equipped division could be made spare, by rearrangement of subscribers in the divisions. Extensive rearrangement was necessary to make one of the divisions spare, but the others were fairly simple, rearrangement of only a small number of subscribers being involved. Subscribers not involved in the transfer to the director exchange were eliminated from these divisions by rearrangement to other divisions, so that, on the withdrawal of the main frame pegs to disconnect from the old exchange, all traffic to the 1st selectors would stop. The 1st selectors, having been connected prior to the transfer, via a line reversing relay, to the banks of 1st code selectors and modified so that metering conditions would

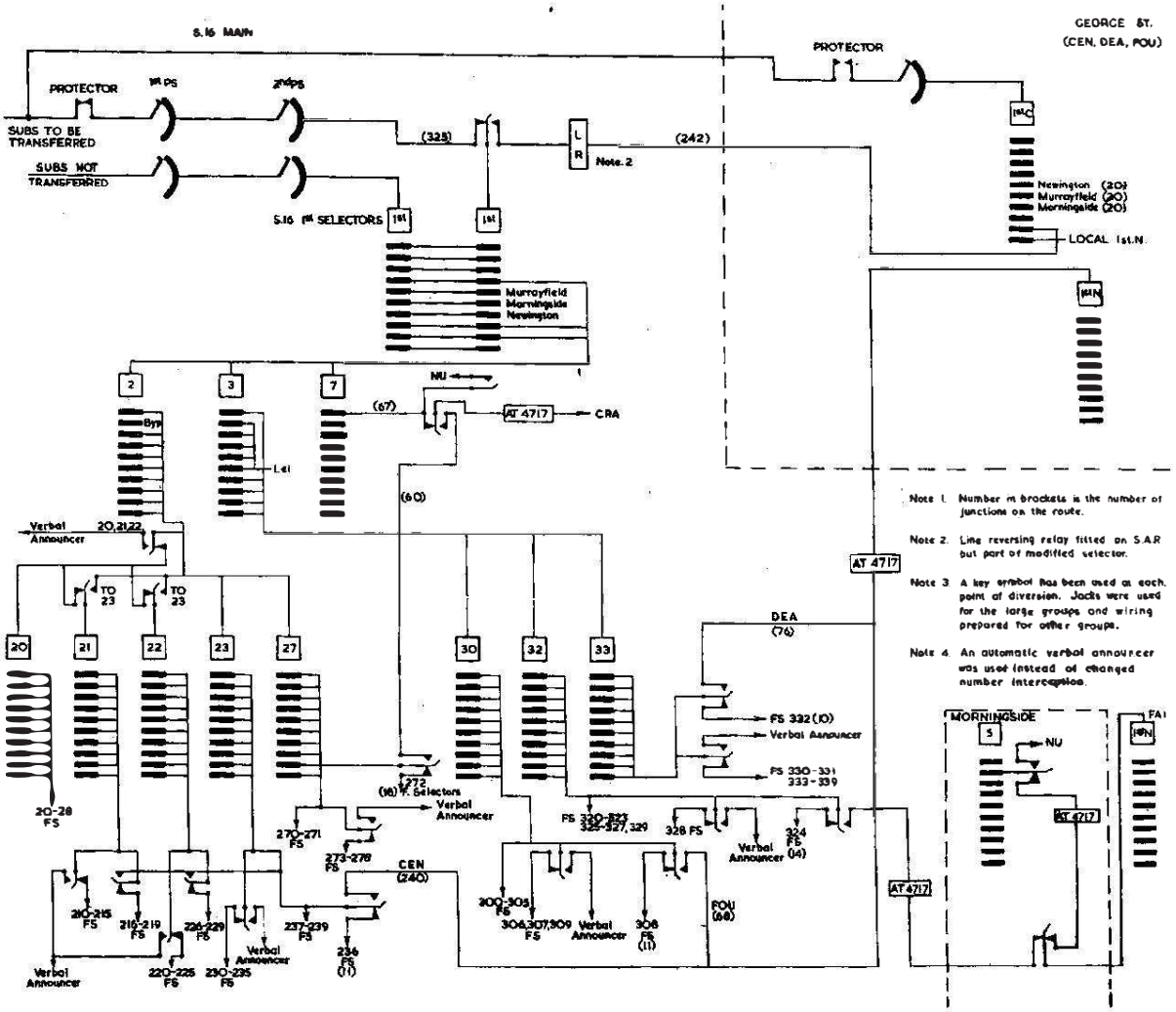


FIG. 2.—SKELETON TRUNKING DIAGRAM SHOWING DIVERSION POINTS FOR TRANSFER OF 5,200 SUBSCRIBERS FROM S.16 MAIN EXCHANGE TO GEORGE STREET DIRECTOR EXCHANGE.

operate the line reversing relay, were ready to accept traffic from the director exchange to the S.16 network. The number of selectors which were modified in this manner was 325. As a precaution against the possibility of an odd subscriber having been missed from the necessary rearrangement, all 2nd preselectors concerned were engaged as a transfer operation. Fig. 2 shows, in skeleton form, the trunking arrangements associated with the transfer, key symbols being used to indicate diversion points although keys were not actually used at all such points.

The initial digit 4, 5 or 6 of 5-digit numbers determines the destination of the call: Newington (4), Morningside (5), Murrayfield or Corstorphine via Murrayfield (6). As this initial digit is part of the routing code (21) 4, (21) 5, (21) 6, the director can route such calls to the objective exchange. Incoming selectors at these exchanges have therefore been modified to accept loop impulses and transmit back to the director a reversal, delayed to avoid metering on "busy," when the call matures. This scheme, which was proved satisfactory on a working route (Craiglockhart-Murrayfield) before the main transfer, has the advantage that it diverts traffic from the main exchange. Manual hold and other facilities provided by the loop-to-leg relay set are not required on calls from director to S.16 subscribers.

Prior to the transfer, the five 3rd selector levels which were to be used after the transfer to route calls from the S.16 network to the director exchanges were wired and equipped to carry traffic to the 500 final selector multiple concerned. Immediately after the transfer, however, they would be required to carry traffic to 10,600 director lines, CEN DEA FOU 7,000, CRA 2,400 and FAI 1,200. This called for the provision of switching facilities which could be used to expand rapidly the traffic-carrying capacity of the groups and divert the levels to the 1st numerical selectors in the director exchanges.

Level 236 presented the biggest problem, as before transfer it was routed to 11 final selectors whereas after transfer it carried 240 junctions. Level 23 was completely recabled to a new T.D.F. to provide the necessary number of groups to take the 330 switches required on that level. Additional switches were diverted from ceased levels 22 and 21. The pre-transfer grading was formed, and jumpering for the extended grading prepared, before the transfer. During the week-end immediately after the transfer, the new grading was formed.

Level 236 was recabled to a new T.D.F. and level 6 of the 3rd selectors in the 22 and 21 groups which were to be used to increase the 23 group was also wired to this T.D.F. Here jumpers were set but not connected; instead, the individual circuits were cabled to a change-over frame where each circuit was connected to two jacks. The inner springs of one set of jacks were commoned to reduce the grading to the 11 final selectors and the jacks were left without pegs. The other set of jacks was pegged and the inner springs wired to leg-to-loop relay sets connected to junctions to the director exchange. As a transfer operation pegs were inserted to cut the common from the individual circuits and pegs were withdrawn to connect to the leg-to-loop relay sets. The arrangement was complicated by the fact that levels 6, 7, 8 and 9 of the 21 and 22 groups, which were being transferred to the 23 group, had to be diverted to 236, 7, 8 and 9. Other levels were dealt with, in principle, in the same way. Fig. 3 shows, in simplified form, the trunking diagram for the Rose Street exchange on completion of the transfer.

ROSE STREET S.16 MAIN AFTER TRANSFER

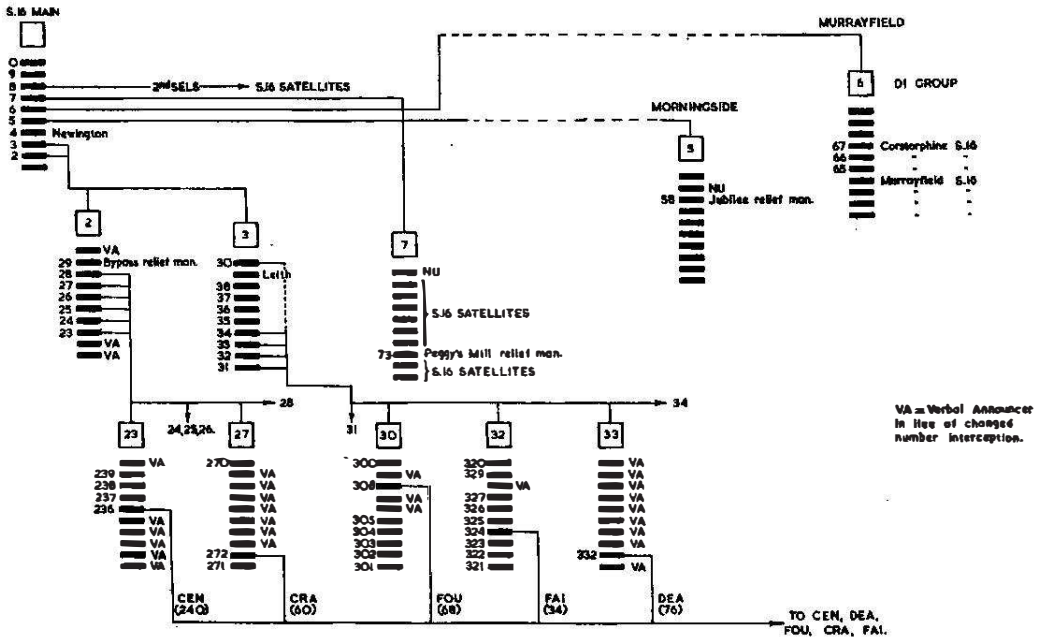


FIG. 3.—TRUNKING DIAGRAM OF ROSE STREET (S.16 MAIN) AFTER THE TRANSFER.

Changed-number Arrangements.

The lack of accommodation was responsible for the introduction of a novel " changed number " facility. Normal changed number facilities could not be provided, and for a period it was thought that " N.U. tone " was the only solution, but the suggestion was made that a verbal announcement might be the solution. This suggestion was pursued and with complete co-operation between the various branches concerned at Area, Regional and Headquarters level, an E.M.I. Tape Recorder and a Provincial Distribution Speaking Clock Amplifier were provided. A competition was run among the local telephonists to choose one with the most suitable voice to make a record to tell subscribers who dialled transferred numbers, " The number you are calling has been changed. Will you please consult the new telephone directory."

FUTURE CONVERSION PROGRAMME.

The next stage in the conversion is the provision of the first instalment of the new permanent director exchange which will replace the old S.16 main exchange in the Rose Street building. This will be a 2,100-line exchange installed in part of the space made available by the transfer of 5,200 subscribers to George Street.

The first of the new exchange buildings, and a key point in the conversion to director, is nearing completion at Fountainbridge. This will be equipped with a 7,300-line director exchange and the director area tandem exchange. More or less simultaneously with this, Abbeyhill director exchange will be installed in an extension to the existing Abbeyhill exchange building.

George Street subscribers with DEAn and FOUntainbridge numbers will be transferred to the Rose Street director and the permanent Fountainbridge exchanges respectively, Rose Street director taking the name DEAn temporarily. All the remaining Fountainbridge area subscribers from the S.16 main and adjacent satellites will go to establish, in its permanent form, the Fountainbridge exchange. Abbeyhill may be ready for service about the same time as Fountainbridge permanent exchange and will probably be converted at the same time. The subscribers in the next 2,300 S.16 multiple to be cleared will be divided on a geographical basis and transferred to director equipment in Rose Street and George Street.

As the third additional exchange, in the central area, will be required in the near future (the name WAVerley has been chosen), and it has been agreed that the name CENtral will be changed when the third new building is ready (name not yet decided), it is probable that George Street will continue as a three-name exchange until the Dean permanent exchange is ready for service. The use of the name WAVerley and the name to replace CENtral will avoid the use of CENtral for new subscribers and those converted on future transfers.

Following the recovery of the 2,300-line S.16 main exchange, an additional 2,400-line director equipment will be installed in the Rose Street building, making a total of 4,500, and when this is ready for service it is hoped that Dean permanent exchange will also be available. All the Dean subscribers will then be transferred to the new Dean exchange, leaving the whole of the 4,500 director multiple in Rose Street to accommodate the next group of S.16 main exchange subscribers to be converted. At this stage, the Rose Street equipment will take the exchange name WAVerley.

With a 7,000-line director exchange in George Street, and a 4,500-line director exchange in Rose Street, all the S.16 subscribers' equipment on the ground floor at Rose Street will be recovered, thus making space available for the extension of the Rose Street (WAV) director equipment to cater for the conversion of the remaining S.16 main exchange subscribers and those that may still be connected to the relief manual exchange serving the central area.

When the third new building is provided in the area marked P (Fig. 1) and the equipment is ready for service, subscribers will be transferred from the George Street exchange. The equipment installed in George Street will then be recovered.

Fig. 4 shows in block schematic form the various stages in the conversion of the Central area. The plan is subject to revision if the building or equipment programme is not maintained or the forecast development alters.

The 1945 multi-exchange area will be extended, during the conversion period, to include Musselburgh, an exchange area adjoining Portobello. This precludes the use of the name Murrayfield shown on the exchange area map, but as Murrayfield is only a Departmental name at present, subscribers having Edinburgh numbers, no serious controversy should arise on this point. Another name has been suggested, but alternatives are still under consideration.

Owing to an accommodation problem in the Morningside area consideration is being given to the introduction of another exchange in the area to replace the existing manual relief exchange, Jubilee, shown on the trunking diagrams.

The dialling scheme adopted imposes certain limitations on the order of conversion, requiring as it does the conversion of subscribers having numbers with the first three digits equivalent to the alphabetical code of a director exchange before that exchange can be converted. Thus, Murrayfield on level 6 must be converted before calls to Morningside and Newington can be routed via MOR (607) or NEW (639). Newington on level 4 must go before Granton, GRA (472), and Morningside on level 5 before Leith, LEI (534). When the plan was prepared this disadvantage caused no great difficulty as the conversion programme based on exhaustion of number range and availability of accommodation fitted into the scheme and no serious difficulty has yet become apparent.

Table I shows the exchanges outside the main exchange area which have still to be converted.

Conclusion.

The conversion of a complete non-director area to director working should be firmly based on a scheme which eliminates, as far as possible, the use of codes which are not shown against each subscriber's number

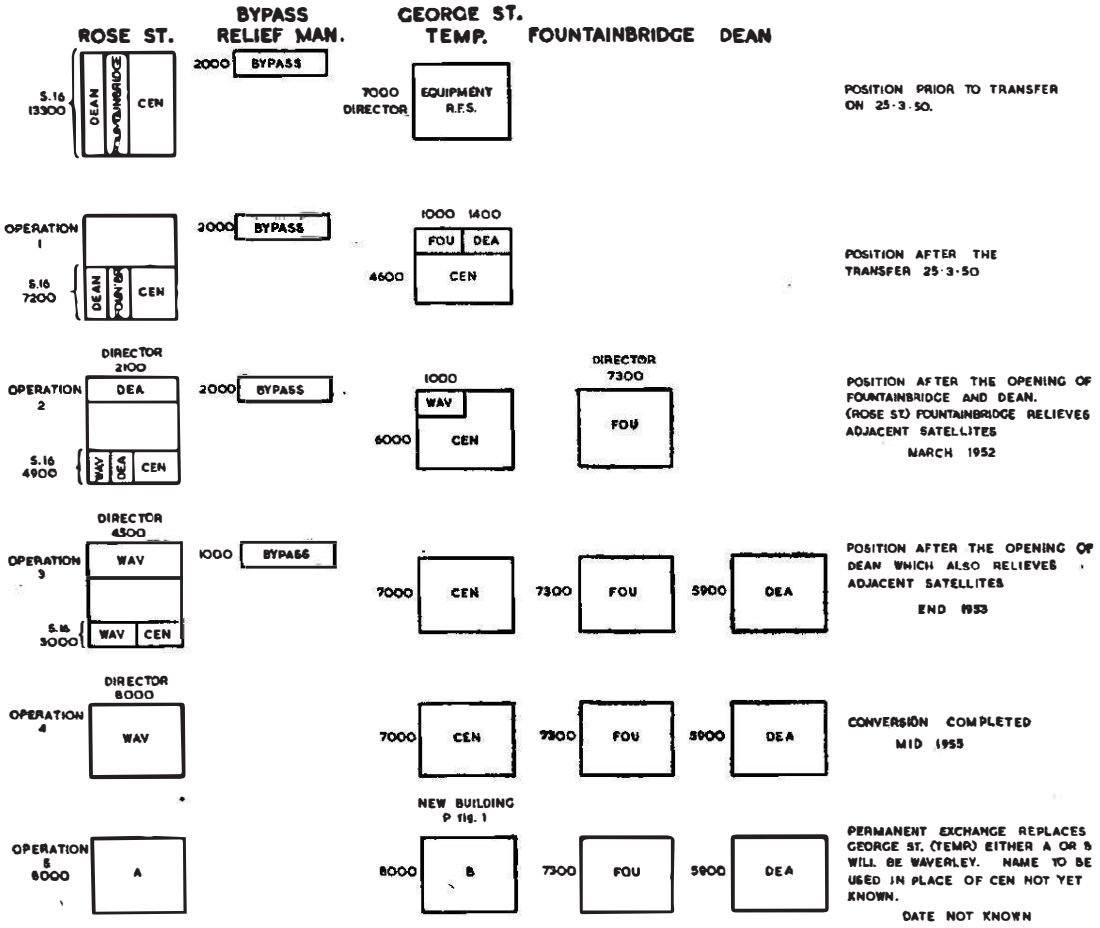

ROSE ST.
BYPASS RELIEF MAN.
GEORGE ST. TEMP.
FOUNTAINBRIDGE
DEAN
POSITION PRIOR TO TRANSFER ON 25·3·50.
POSITION AFTER THE TRANSFER 25·3·50
POSITION AFTER THE OPENING OF FOUNTAINBRIDGE AND DEAN. (ROSE ST) FOUNTAINBRIDGE RELIEVES ADJACENT SATELLITES
MARCH 1952
POSITION AFTER THE OPENING OF DEAN WHICH ALSO RELIEVES ADJACENT SATELLITES
END 1953
CONVERSION COMPLETED MID 1955
PERMANENT EXCHANGE REPLACES GEORGE ST. (TEMP) EITHER A OR B WILL BE WAVERLEY. NAME TO BE USED IN PLACE OF CEN NOT YET KNOWN.
DATE NOT KNOWN
NEW BUILDING

FIG. 4.—STAGES IN THE CONVERSION OF THE CENTRAL AREA TO DIRECTOR WORKING.

TABLE I.

Exchange in order of conversion	S.16 subscribers' dial	Remarks
Director Area Tandem	—	March, 1952.
Abbeyhill	ABB (222)	March, 1952.
Portobello	POR (707)	
Corstorphine	COR (207)	
Musselburgh	"0"	As Musselburgh is excess fee from S.16 exchanges, MUS (687) will be intercepted to "0." Director exchanges dial MUS.
Ravelston	RAV (728)	Replace Murrayfield S.16 exchange. Alternative names under consideration.
Additional Exchange, Morningside Area	Name not chosen	If found necessary to replace Jubilee relief manual exchange.
Woodcroft Jt. Tk. ..	"0"	Includes Trunk and Toll Tandem.
Davidson Mains ..	DAV (328)	Opens after DEAn permanent as some 800 subs transfer from this area to Dean.
Morningside	MOR (607)	
Newington	NEW (639)	
Liberton	LIB (542)	
Colinton	COL (205)	
Leith	—	Conversion completed Target Date, 1957
Granton	—	

in the directory and there should be some obvious distinction between telephones connected to non-director exchanges and those connected to director exchanges, as it is not possible for director subscribers to have the same dialling instructions as non-director subscribers. It is also desirable to avoid having subscribers connected to non-director levels which are the numerical equivalent of director codes. It will be appreciated, however, that the availability or lack of accommodation may be a deciding factor when considering the policy to be adopted.

A conversion of this type is both extensive and complicated and credit is due to the Edinburgh Area staff for the very efficient way in which the conversion work has been carried through to date. Much work remains to be done, however, and no doubt other novel ideas will occur during detailed planning and contribute towards a speedy and successful completion of the whole of the complex operation now in progress.

Acknowledgments.

The author thanks his colleagues in the Telecommunications and Engineering Branches of Post Office Headquarters, Scotland, for suggestions and assistance in the preparation of this article.

A Survey of Modern Radio Valves

W. J. BRAY, M.Sc.(Eng.), A.C.G.I., D.I.C.†

Part 6(a).—Valves for Use at Frequencies Above 3,000 Mc/s

U.D.C. 621.385 : 621.396.615.14

In this concluding part of the series*, the principles of operation, methods of construction and characteristics of low-power oscillator and amplifier valves suitable for use in radio and wave-guide relay systems operating at frequencies above 3,000 Mc/s are described. The valves referred to include klystron amplifiers, travelling-wave and electron-wave amplifiers, grounded-grid triode amplifiers, klystron oscillators and continuous-wave magnetrons. The suitability of the oscillators for amplitude, frequency or pulse modulation is discussed.

Introduction.

THIS part of the survey of modern radio valves is mainly concerned with low-power valves suitable for use in single or multiple-link radio relay systems operating in the frequency bands around 4,000 and 6,000 Mc/s allocated at the Atlantic City Conference (1947) for civil communication purposes. Some consideration is also given to valves operating at frequencies of the order of 30,000 Mc/s, such as may be used in the more distant future in long-distance relay systems using waveguides.

In radio relay systems operating at frequencies above 3,000 Mc/s the aerials employed are of high gain, the links are usually less than 40 miles long and the radio paths are unobstructed. Under these conditions transmitted powers of a few watts or less are sufficient to provide the required signal-to-noise ratio. The transmitter usually consists of a low-power oscillator followed by an amplifier, since a low-power oscillator is more readily stabilised in frequency and modulated than is a high-power oscillator. Low-power oscillators are also needed for frequency changing in super-heterodyne receivers.

Although the power output required from transmitting amplifiers is only of the order of a few watts, it is desirable for the efficiency to be reasonably high, e.g. 10 per cent. or more, to reduce the power required from the high-tension supply—an important factor in systems with unattended stations. As already explained in the preceding article[1] in this series, with conventional valves of the space-charge control type the power output, efficiency and gain decrease as the frequency is increased owing to limitations imposed by (*a*) the transit time of the electrons, and (*b*) the effects of the inductance of leads to the electrodes. These limitations can be minimised by using grounded-grid triodes with very small clearances between the electrodes[2]; but for practical purposes the useful upper limit of frequency is at present about 4,000 Mc/s for amplifiers capable of about a watt output with an efficiency approaching 10 per cent.

Although some improvements in these figures can be expected it is apparent that for frequencies much above 4,000 Mc/s valves of a fundamentally different type are needed to obtain adequate gain, power output and efficiency. Fortunately, for frequencies above about 2,000 Mc/s, it is possible to use valves of the velocity-modulation (V.M.) type [3, 4, 5] as amplifiers, oscillators and frequency-multipliers, typical valves being klystrons and travelling-wave valves. In V.M. valves use is made of the fact that the electrons take an appreciable time to travel from the cathode to the collector electrode. The electron beam is first modulated in velocity by the applied radio frequency signal with the result that as the electrons move along they become bunched, i.e. the amplitude of the beam current at a given point varies at radio frequency and the electron beam is capable of delivering power to the output circuit. In addition to the V.M. valves, magnetrons are available as efficient oscillators for continuous-wave (C.W.) or pulse-modulation (P.M.) systems.

Valves may be classified under two main headings:

(i) those suitable for use as amplifiers but which may be made to oscillate by the provision of an external feed-back path; and

(ii) those with internal feed-back, or its equivalent, which are suitable for use only as oscillators.

Amplifier Valves

Velocity-modulation Klystron Amplifier.

A double-resonator klystron amplifier is shown in simplified form in Fig. 1; it consists essentially of two

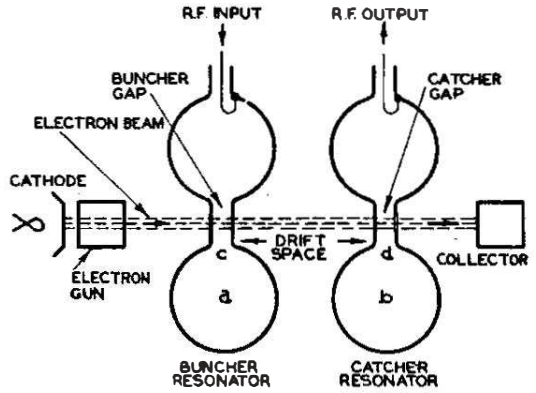


Fig. 1.—Simplified Sketch of Double-Resonator Klystron Amplifier.

cavity resonators, *a* and *b*, termed the "buncher" and "catcher" respectively, which are traversed by an electron beam. Each of the resonators shown consists of a toroidal metal enclosure with two plane surfaces separated by a narrow gap (*c*, *d*) at the centre, each surface having a hole in the centre to permit the passage of the electron beam. In practice, however, the resonators may be other than toroidal, and in some valves the holes through which the electron

†Assistant Staff Engineer, Radio Experimental and Development Branch, E.-in-C's Office.

*Because of printing difficulties it has been necessary to publish Part 6 in two sections.

beam passes may be spanned by a rudimentary grid instead of being completely open. When the buncher is excited by radio frequency power fed in by means of a suitable coupling loop or probe, a relatively strong alternating electric field is set up across the narrow gap, provided the applied frequency is close to the resonance frequency of the buncher. Under these conditions the velocity of the electrons is varied by the electric field as they pass across the gap, some being accelerated when the direction of the electric field is opposite to that of the electron flow and others retarded when the field reverses. (The apparent anomaly in this statement is due to the fact that an electron has a negative charge.) Thus, some electrons leave the buncher gap with greater than average *velocity* and others with less. As the electrons pass along the space between the buncher and catcher—the " drift " space—the faster-moving electrons overtake the slower electrons and form bunches or groups with greater than average *density*, separated, of course, by comparatively empty spaces. This action is illustrated in Fig. **2** for eight equally spaced instants of

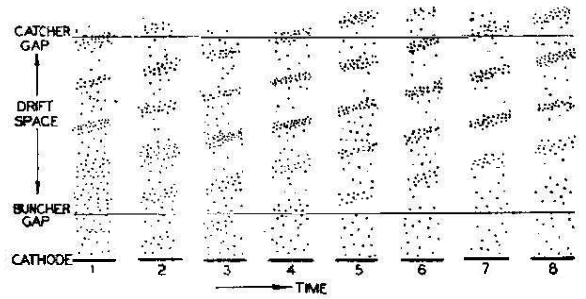


FIG. 2.—ELECTRON BUNCHING IN A KLYSTRON AMPLIFIER.

time corresponding to a total of two-and-a-half radio frequency cycles. The time of transit through the buncher gap is a small fraction, usually about one-third, of a radio frequency cycle. The time of transit through the drift space on the other hand, is much longer and may amount to several radio frequency cycles in order to obtain effective bunching. The average time spent in the drift space depends on the average velocity of the electrons and therefore on the direct accelerating potential between the cathode and the cylinder which forms the electron gun. The latter and the resonators are normally earthed and the cathode is usually held below earth potential by some 1,000 to 3,000 V.

The electron beam has thus become modulated in intensity at the applied radio frequency and the electron bunches (which correspond to a pulsating current) give rise to an alternating field between the grids or in the gaps of the output, or catcher, resonator. The phase relationship between the electron bunches and the field is dependent on the impedance of the resonator, just as the phase relationship between current and voltage in an ordinary A.C. circuit is dependent on its impedance. When maximum power is abstracted from the resonator, the direction of the field across the gaps is such as to cause the electrons to give up the maximum amount of energy, i.e., the direction of the field must be such as to cause maximum retardation of the electrons. Under suitable operating conditions more radio frequency power can be taken from the catcher resonator than is applied to the buncher, i.e., the valve functions as an amplifier. The difference between the R.F. output power and the R.F. input power comes from the power in the electron beam, i.e. the product of the beam current and the accelerating voltage ; only a fraction of the beam power is, however, abstracted at the catcher and the remainder appears as heat due to electron bombardment of the collector electrode.

The efficiency (ratio of R.F. power output to beam power) of an ideal klystron amplifier is 58 per cent. ; in practice various factors, such as damping of resonators by the inherent losses and by the beam, interception of the beam current by the grids and walls of the resonators, and the limitation of the peak R.F. voltage across the catcher gap to a value not exceeding the beam voltage, reduce the efficiency to a few per cent.

The gain of a klystron amplifier can be improved by using three resonators in cascade along the same electron beam; one advantage of this arrangement is that it can be designed to yield the maximum power output with a comparatively small drive power. With a small amount of driving power the bunching due to the first gap is relatively slight, but it excites the second resonator and this produces more velocity modulation than was produced by the first resonator, and thus enables optimum bunching to be obtained at the gap of the third, i.e. the output, resonator.

Characteristics of typical klystron amplifier.—The experimental valve VX318 developed at the Admiralty Signal and Radar Establishment, Bristol, during the war, is an example of a triple-resonator klystron amplifier ; a section of the valve is shown in Fig. **3** and an external view in Fig. **4**.

The characteristics of a typical klystron amplifier valve VX318 are as follows :

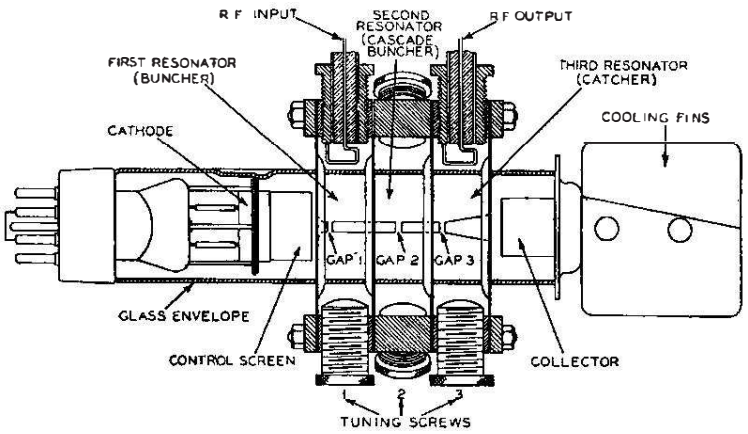


FIG. 3.—SECTION OF TRIPLE-RESONATOR KLYSTRON AMPLIFIER, VX 318.

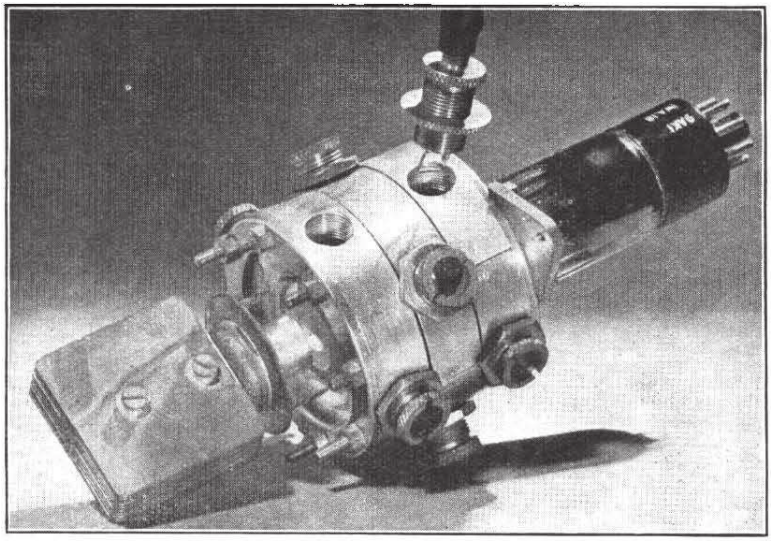


FIG. 4.—TRIPLE-RESONATOR KLYSTRON AMPLIFIER, VX 318.

Mid-band frequency	3,000 Mc/s
Bandwidth (3 db. below maximum output)	3 Mc/s
Beam voltage	3 kV
Cathode current	80 mA
Maximum R.F. power output	10 W
Gain (under linear conditions)	20 db.
Efficiency	4 per cent.

It is evident that the bandwidth is too small for many radio relaying applications and it is found that if the bandwidth is increased, e.g. by damping the resonators, the gain is appreciably reduced.

For the lower signal levels the R.F. output power of a klystron amplifier is proportional to the R.F. input power, but as the latter is further increased the output power first reaches a maximum and then decreases. The condition of maximum R.F. output corresponds to optimum bunching of the electron beam; with smaller R.F. inputs the bunching is non-optimum and approaches a sinusoidal variation of the beam current with time; larger R.F. inputs cause the electron beam to become "overbunched." Overbuncbing means that instead of the optimum condition in which one narrow bunch of electrons is produced for each R.F. cycle, the bunch spreads and may become in effect two smaller bunches displaced in phase and time from the optimum, so reducing the R.F. power obtainable from the electron beam.

The characteristics of the experimental valve VX318 discussed above do not necessarily represent the best performance that can be achieved with klystron amplifiers; for example, Touraton, Zwobada and Dumousseau[6] have described an improved klystron using an annular instead of a circular electron beam. For this valve a H.T. voltage of some 8,000 V was needed, and a power output of 12 W with a gain of 16 db. was obtained, the bandwidth being 50 Mc/s at 3,000 Mc/s and the efficiency 4·4 per cent.

Noise in klystron amplifiers.—The performance of a klystron amplifier with regard to noise is conveniently expressed in terms of the noise factor, i.e. the ratio of the highest signal-to-noise ratio theoretically available at the source to that obtained in practice at the output of the amplifier. The noise factor of a typical (3,000 Mc/s) klystron is of the order of 30 db., which should be compared with about 12 to 15 db. for a super-heterodyne receiver operating on the same frequency and having a crystal mixer as the first stage.

The noise in a klystron amplifier arises chiefly as a result of the inherent fluctuations of current density in the electron stream; the fluctuations of beam current induce voltages in the buncher resonator which, in turn, give rise to random velocity modulation and bunching of the electrons and hence amplified shot noise in the catcher resonator; the fluctuations of beam current also excite the catcher directly.

Various theoretical analyses have been made of methods for reducing the noise, e.g. by balancing the amplified shot noise against that directly induced in the catcher, but as yet there appears to be no experimental evidence that a useful reduction of the noise factor can be achieved.

Travelling-wave Amplifiers.

The first travelling-wave amplifier[8, 9] was developed by R. Kompfner working for the Admiralty at the Clarendon Laboratory, Oxford, and at Birmingham University, during the period 1942-1944. The feature of major interest in the travelling-wave valve is the remarkably wide bandwidth over which amplification is possible; bandwidths of some 600 Mc/s are obtained in valves now in production for use at frequencies of the order of 4,000 Mc/s and bandwidths exceeding one octave have been obtained in experimental valves.

The travelling-wave valve is relatively simple in construction—it consists primarily of a closely-wound helix, Fig. 5, along which the R.F. electro-magnetic wave is propagated. An electron beam is made to travel down the centre of the helix, a longitudinal magnetic field produced by a direct current carrying solenoid outside the valve being used to focus the

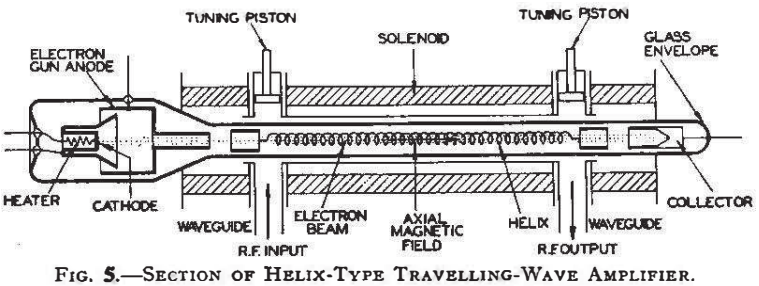


FIG. 5.—SECTION OF HELIX-TYPE TRAVELLING-WAVE AMPLIFIER.

electron beam so that most of the current in the beam is received by a collector electrode. When the axial component of the velocity of propagation of the R.F. wave along the helix is nearly the same as the velocity of the electrons in the beam, interaction between the wave and the beam occurs, with the result that under suitable conditions the amplitude of the wave increases continuously after a certain point on the helix. The electron velocity is determined by the beam voltage, for example, a 2,500-V beam travels at about one-tenth of the velocity of light. Since the wave travels round the turns of the helix at about the velocity of light the pitch of the helix must be approximately one-tenth of the circumference of a turn, in the example quoted.

The gain of travelling-wave valves is sometimes limited by the onset of oscillations due to waves reflected from the output circuit and which travel back along the helix to the input circuit. This difficulty can be minimised by the use of distributed attenuation produced by a film of graphite near the middle of the helix; such attenuation does not prevent the valve from developing a gain, its main effect is to divide the helix into "buncher" and "catcher" sections as in the klystron, the wave energy being carried in the forward direction by the electron beam and prevented from travelling backwards along the helix by the attenuation due to the film.

The characteristics of typical valves designed in the Research Laboratories of Standard Telephones & Cables, Ltd., by D.C. Rogers[10] are given below.

	VX7039 *Low-power amplifier*	*VX7049* *Power amplifier*
Beam voltage	1,400 V	3,000 V
Cathode current	5 mA	15 mA
Collector current	3 mA	14 mA
Gain under linear conditions	22 db.	19 db.
Frequency range	3,600-5,000 Mc/s	3,600-4,200 Mc/s
R.F. power output	0·15 W	2·5 W
Efficiency	2·1%	5·5%

A travelling-wave valve VX 7049 is shown in Fig. 6, together with short sections of waveguide used for coupling to the input and output ends of the helix, and the solenoid for producing the magnetic field for focusing the electron beam. This valve requires air-blast cooling of the collector in order to dissipate the heat produced at that electrode; the cooling arrangements can be seen on the left of the photograph.

Travelling-wave valves of the types referred to above have reached a state of development such that their use in wide-band radio relay systems can now be envisaged; however, the relatively high noise of these valves precludes their use at extremely low signal levels.

By reducing the dimensions of the helix in proportion to the wavelength the operating frequency can

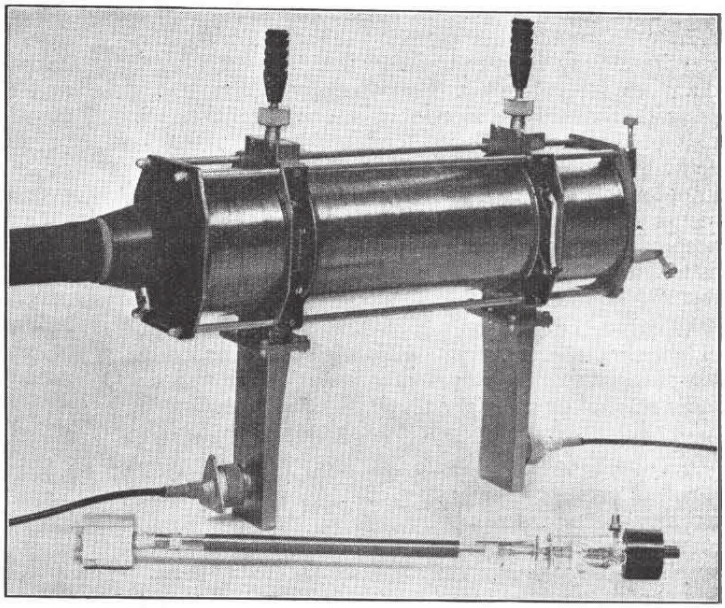


FIG. 6.—TRAVELLING-WAVE AMPLIFIER, VX 7049.

be increased and it has been reported from the Bell Telephone Laboratories that a gain of some 4 db. has been achieved at 50,000 Mc/s (0·6 cm. wavelength) with a helix having an inside diameter of 1 mm. and a length of 3·5 cm.[11]

Structures other than the helix may be used to slow down the R.F. wave until its velocity is approximately equal to that of the electrons, but in general it appears difficult to improve on the helix when gain and bandwidth are the primary considerations.[12] When large power outputs are required, structures such as corrugated waveguides have been employed. In one type of corrugated circular waveguide the corrugations are formed by metal discs assembled with spacers between them on an axial rod, this assembly being placed in a cylindrical metal tube. An annular electron beam is used in this type of valve, the beam being passed between the periphery of the discs and the outer cylinder. In a water-cooled valve of this type designed in the Federal Telecommunication Laboratories, U.S.A., a power output of 100 W was obtained at 4,700 Mc/s.[11]

Corrugated waveguide structures have also been employed at wavelengths of the order of 1 cm.; a gain of some 9 db. at 25,000 Mc/s has been reported from the Bell Telephone Laboratories, using a "spatial harmonic" mode of operation.[11]

Noise in travelling-wave valves—Noise in travelling-wave amplifiers arises from random fluctuations of the density, and to a less extent of the velocity, of the electrons forming the beam. The theory of this subject is not at present completely developed although important advances have been made by F. N. H. Robinson and R. Kompfner at the Services Electronic Research Laboratory in this country, and by J. R. Pierce, Bell Telephone Laboratories, and L. M. Field, Stanford University, in the U.S.A. The best noise factors obtained experimentally are some

10 to 12 db.; these low-noise valves employ a relatively small beam current (about 0·2 mA) and require a very narrow electron beam (about 1 mm. diameter) traversing a long, narrow helix. It is essential that the electrons shall travel parallel to the axis of the beam without spiralling and that interception of the beam by the helix shall be very small in order to minimise partition noise. These requirements necessitate careful design and extremely accurate mechanical construction of the electron gun, as well as a high degree of uniformity in the magnetic focusing field.

Whether these difficulties can be overcome to an extent which would permit of quantity production of low-noise travelling-wave valves and their use in radio relay systems is at present an open question.

Electron-wave Amplifiers.

An interesting new type of V.M. amplifier has recently been described by A. V. Haeff,[13] J. R. Pierce and W. B. Hebenstreit[14] and others. This amplifier is approximately equivalent to a travelling-wave amplifier in which the helix is replaced by a second electron beam, as shown in Fig. 7.

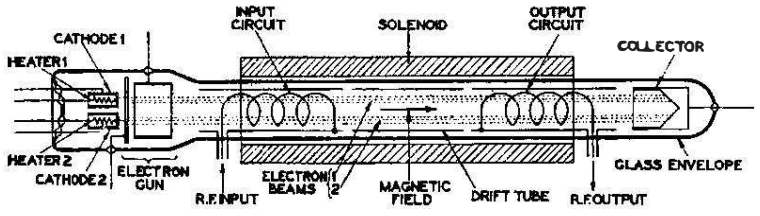


FIG. 7.—SECTION OF DOUBLE-BEAM ELECTRON-WAVE AMPLIFIER.

The two electron beams come from separate cathodes differing in potential by some 50 volts so that the beams have slightly different velocities. Both beams are velocity modulated by the R.F. input signal and pass through the same drift-tube where interaction occurs between the electrons in one beam and the electric field of the other, and vice versa. This interaction results in variation of the beam current density, i.e., in bunching; the beams are thus enabled to deliver radio frequency power to the output circuit. The input and output circuits are usually short lengths of helix, but this is not essential and resonators similar to those in klystrons can be employed. Another form of the valve exists in which a single electron beam is used, but the inner and outer portions of the beam are caused to travel at slightly different velocities by suitable adjustment of the potential of the drift-tube relative to the cathode.

Within the electron beam, gains of 80 db. or more are claimed to be possible; however, this neglects the imperfect coupling between the input and output circuits and the electron beam. In practice a net gain of 46 db. at 3,000 Mc/s has been achieved[15]; it is interesting to note that electron-wave amplification is also possible at much lower frequencies and a valve with 33 db. net gain at 255 Mc/s has been described.[14] The bandwidth limit set by the electron beam itself is of the order of 30 per cent. of the mid-band frequency, but in practice it is restricted by that of the input and output circuits. Assessments of the power output and efficiency under large signal conditions and the noise factor under small signal conditions are not available as yet, but it seems unlikely with the present form of the valve that these will be as good as in conventional travelling-wave amplifiers. However, the electron-wave valve may find applications as an amplifier of signals of medium power level, particularly when a high gain is required. Furthermore, the absence of a metallic slow-wave structure may make the valve useful for amplification of millimetric waves, since structures such as the helix or corrugated waveguide have to be made very small for such wavelengths.

Magnetron-type Travelling-wave Amplifiers.

The efficiency of conventional travelling-wave amplifiers of the Kompfner-Pierce type is generally low, being usually less than 10 per cent., whereas magnetron oscillators may have efficiencies exceeding 50 per cent. An attempt has been made by R. R. Warnecke and his associates of the Compagnie Generale de Télégraphie Sans Fil (Paris) to devise a travelling-wave amplifier,[16] which incorporates certain features of the magnetron, viz., the use of a magnetic field normal to the plane in which the electrons move, thus causing the electrons to travel, in the limit, in cycloidal paths. The resonant cavities of a magnetron are replaced by a flattened helix bent into a circle, the input and output being separated by a metallic partition. Output powers of some 50 W, overall efficiencies of 25 per cent. and gains of about 7 db. have been reported at 23 cm. wavelength (1,310 Mc/s).

Grounded-grid Triode Amplifiers.

A grounded-grid triode, BTL1553, for use at 4,000 Mc/s has been designed by J. A. Morton of the Bell Telephone Laboratories.[2] This represents an appreciable advance in the upper frequency limit for triodes, an improvement which has been obtained by:—

(*a*) reducing the grid-cathode spacing and the spacing between the turns of the grid wires,

(*b*) maintaining exact parallelism between the planes of the grid wires and the cathode,

and

(*c*) increasing the cathode emission.

The main dimensions of the BTL1553 triode are:—

Cathode-grid spacing	0·6 mil.
Grid wire thickness	0·33 mil.
Grid wire turns	1,000/in.
Grid-anode spacing	10 mils.

It will be apparent that special manufacturing techniques are needed to maintain these small spacings satisfactorily. For example, the cathode is an oxide coating on a nickel base mounted in a ceramic ring, the cathode assembly being precision-ground to a flat surface. The grid wires are wound on

a molybdenum former and are tensioned to within about 50 per cent. of the breaking stress of the wire to maintain an accurately plane surface. The grid structure and the cathode assembly are spaced by a thin copper shim plate and tightly clamped together.

The characteristics of this valve when used as an amplifier with the appropriate resonators as input and output circuits, are as follows :—

Mid-band frequency	4,000 Mc/s
Bandwidth (3 db. below maximum output)	80-100 Mc/s
Gain, Class A operation	7-10 db.
Noise factor, Class A operation	14-16 db.
Gain, Class B operation	4-6 db.
Maximum R.F. output, Class B operation	0·5-1 W
Anode dissipation	6 W
Efficiency	7·5-15%

It will be observed that the characteristics of the valve make it suitable for use in both the initial and final stages of microwave repeaters, and it is understood that the valve is in production by the Western Electric Company, under the coding **WE416A**, for use in the New York-Chicago radio relay system.

A further development in grounded-grid triodes has been announced from the Philips Research Laboratories at Eindhoven, Holland.[17] A porous tungsten cathode (the Lemmens cathode) is used in this new triode and the active materials are inserted inside the cathode; this avoids the usual oxide coating and enables a high and uniform emission to be obtained. As a result of the very effective space-charge smoothing due to the uniform emission, the noise factor is remarkably small and a value of 7 db. at 3,000 Mc/s is claimed. Under large signal conditions a power output of 0·5 W and gain of 10 db. with a bandwidth of 50 Mc/s are obtained. The data quoted refer to early experimental samples and the valve has not yet reached the production stage.

(To be continued)

Bibliography.

[1] "Valves for Use in the Range 30 to 3,000 Mc/s," R. W. White, *P.O.E.E.J.*, Vol. 43, p. 78.

[2] "A Microwave Triode for Radio Relay," J. A. Morton, *Bell Laboratories Record*, Vol. 27, p. 166, May, 1949.

[3] "Velocity Modulated Thermionic Tubes," A. H. W. Beck, Cambridge University Press, 1948.

[4] "Klystrons and Microwave Triodes," D. R. Hamilton, J. K. Knipp and J. B. Horner-Kuper, M.I.T. Radiation Laboratory Series, McGraw-Hill Book Co., 1948.

[5] "Velocity Modulation Valves," L. F. Broadway, C. J. Milner, D. R. Petrie, W. J. Scott and G. P. Wright, *J.I.E.E.*, Vol. 93, Part IIIA, p. 855, No. 5, 1946.

[6] "Tubes Amplificateurs en Ondes Centimétriques Permettant l'Amplification de Signaux Occupant Une Très Large Bande de Fréquencies," Mm. Touraton, Zwobada and Dumousseau, *L'Onde Electrique*, Vol.27, p. 361, October, 1947.

[7] "The Klystron as Amplifier at Centimetric Wavelengths," R. Kompfner, *J. Brit. I.R.E.*, Vol. 7, p. 117, May-June, 1947.

[8] "The Travelling-Wave Tube as Amplifier at Microwaves," R. Kompfner, *Proceedings I.R.E.*, Vol. 35, p. 124, February, 1947.

[9] "Travelling-Wave Tubes," J. R. Pierce, *Bell System Technical Journal*, Vol. 29, Nos. 1-4, January-October, 1950.

[10] "Travelling-Wave Amplifier for Six to Eight Centimetres," D. C. Rogers, *Electrical Communication*, Vol. 26, p. 144, June, 1949.

[11] "Recent Developments in Travelling-Wave Tubes," L. M. Field, *Electronics*, p. 100, January, 1950.

[12] "Some Slow-Wave Structures for Travelling-Wave Tubes," L. M. Field, *Proceedings I.R.E.*, Vol. 37, p. 34, January, 1949.

[13] "The Electron-Wave Tube," A. V. Haeff, *Proceedings I.R.E.*, Vol. 37, p. 4, January, 1949.

[14] "A New Type of High-Frequency Amplifier," J. R. Pierce and W. B. Hebenstreit, *Bell System Technical Journal*, Vol. 28, p. 33, January, 1949.

[15] "Experimental Observation of Amplification by Interaction Between Two Electron Streams," A. V. Hollenberg, *Bell System Technical Journal*, Vol. 28, p. 52, January, 1949.

[16] "The Magnetron-Type Travelling-Wave Amplifier Tube," R. R. Warnecke, W. Kleen, O. Dohler and H. Huber, *Proceedings I.R.E.*, Vol. 38, p. 486, May, 1950.

[17] "Low Level Triode Amplifier for Microwaves," G. Diemer and K. S. Knol, *Philips Research Report*, Vol. 5, p. 153-154, February, 1950.

The Institution of Post Office Electrical Engineers

London Centre

During the summer months the London Centre Committee have been active in formulating a programme of meetings and educational visits for the forthcoming Session. The number of offers of suitable papers has been rather less than that of recent years and in the interests of presenting a well-balanced programme it has been necessary in some instances to solicit papers on specific subjects.

Thanks are due not only to those authors whose papers have been accepted but also to those whose offers have, for the time being at least, had to be rejected.

Ordinary Meetings

Held at the Institution of Electrical Engineers, Savoy Place, W.C.2, commencing at 5.0 p.m.

Monday, 6th November.—"The Anglo-Continental Telephone Service." J. Rhodes, M.B.E., B.Sc., A.M.I.E.E.

Tuesday, 5th December.—"Shared Service." N. V. Knight, B.Sc., A.M.I.E.E.

Informal Meeting

Held in the Conference Room, 4th Floor, Waterloo Bridge House, S.E.1., commencing at 5.0 p.m.

Wednesday, 22nd November.—"Wage Incentive Systems." W. Hawking, T.D., A.M.I.E.E. (N.E. Region).

Arrangements are in train for a Social and Dance to be held in the Armour House Refreshment Club premises, St. Martin's le Grand, E.C.1, on Friday, November 10th, from 7.30-11.0 p.m., and in spite of the Journal printing delay it is hoped that this notification will appear in time to be of interest.

Tickets at a reasonable price will be made available in all Branches in due course and as some limitation on sales may have to be imposed early purchase is desirable.

W. H. F.

Essay Competition 1950/51

The Council offers five prizes of Three Guineas each for the five most meritorious essays submitted by members of the Engineering Department of the Post Office below the rank of Inspector. Draughtsmen, Class II, with less than five years' service on that grade, are also eligible to compete. In addition to the five prizes the Council awards a limited number of Certificates of Merit.

A prize-winner in any previous competition is not eligible to enter, but this restriction does not apply to a competitor who has been awarded a Certificate of Merit only. An essay submitted for consideration of an award in the Essay Competition and also submitted in connection with the Junior Section I.P.O.E.E. prizes, will not be eligible to receive both awards.

In judging the merits of an essay, consideration will be given to clearness of expression, correct use of words, neatness and arrangement, and although technical accuracy is essential, a high technical standard is not absolutely necessary to qualify for an award. The Council hopes this assurance will encourage a larger number to enter. Marks will be awarded for originality of essays submitted.

Hints on the construction of an Essay can be obtained, if desired, upon application to the Secretary at the address given below. Competitors may choose any subject relevant to current telegraph or telephone practice.

Foolscap or quarto size paper should be used, and the essay must not exceed 5,000 words. An inch margin is to be left on each page. A certificate is required to be given by each competitor, at the end of the essay, in the following terms :—

" In forwarding the foregoing essay of ..... words, I certify that the work is my own unaided effort both as regards composition and drawing."

Name (in Block Capitals) .....

Signature .....

**Rank* .....

Departmental Address .....

.....

Date .....

(**If a Draughtsman, Class II, state date of appointment to that grade.*)

The Essays must reach
The Secretary,
The Institution of Post Office Electrical Engineers,
G.P.O. (Alder House), London, E.C.1,
by the 31st December, 1950.

The Council reserves the right to refrain from awarding the full number of prizes or certificates if in its opinion the essays submitted do not attain a sufficiently high standard.

Special Prize of Three Guineas

In addition to the five prizes mentioned above, the Council offers a special prize of Three Guineas for the best essay on :—

" My reactions to the present Essay Competition and my suggestions for improving it."

(The restriction on previous prize-winners does not apply to this essay.)

J. READING,
Secretary.

Junior Section Notes

LIBRARY FACILITIES

Books cost money and very few people can afford to purchase all the books they would wish to have on their own bookshelves and still fewer can afford all the books necessary for reference to keep abreast of developments in the Engineering and Scientific fields. Access to libraries is, therefore, essential. The I.P.O.E.E. Library offers a comprehensive and up-to-date range of books covering Telecommunications, Engineering and allied subjects. The Institution Library is affiliated to Lewis's Scientific Library and any books requisitioned which are not held in the Institution Library are obtained, wherever possible, from Lewis's subject to their being of a character similar to those books contained in the Institution Library. Lewis's catalogue is available for loan as Book No. 931. The Library also has available for loan bound volumes of all I.P.O.E.E. printed papers, prize essays, Junior Section prize papers and unpublished papers recommended by local centres as suitable for inclusion in the library.

All these library facilities are available to a member of a recognised Junior Section on payment of only 6d. per annum.

Copies of the Catalogue and Annual Supplements are held by the local Junior Section Centre Secretaries, who also hold supplies of library requisition forms. Junior Section members requiring books should forward the requisition slips to the Librarian via their Junior Section Centre Secretary for his counter-signature.

Bishop's Stortford Centre

On the 3rd May, 1950, an inaugural meeting was held at Bishop's Stortford, with the object of forming a section to cover the Bishop's Stortford, Epping, Ware, Hertford and Saffron Walden areas.

The meeting opened with a film show, given by the Central Office of Information, and the following films were very much enjoyed :

1. This Britain, No. 22; 2. The Wonder Jet; 3. Public Opinion; 4. Wonders of the Deep; 5. In all Weathers.

After the film show the Cambridge Area Liaison Officer, Colonel T. C. Loveday, addressed the meeting, explaining in some detail the objects of the Junior Section and the advantages to be obtained by the formation of a centre at Bishop's Stortford.

As a result of this address, the meeting decided unanimously to form a centre, and approximately 30 members enrolled immediately.

The officers and committee appointed are :—

Chairman : G. T. Wyer; *Vice-Chairman :* R. A. Collins; *Secretary :* J. Poole; *Treasurer :* W. Worley; *Committee :* H. James, J. S. Rogers, G. E. Dann, R. G. Eve and F. Brackley.

The first committee meeting was held on 16th May, 1950, and the following programme was arranged for the first half of the 1950-51 Session.

September, 1950. Film Show and first Annual General Meeting. Discussion on programme for winter session.

October, 1950.—Lecture, " Astronomy," by R. C. T. Warboys. Visit to University Observatory at Cambridge.

November, 1950.—Lecture, " Faraday Building." Speaker to be announced later. Visit to Faraday Building.

December, 1950.—Lecture, " Internal Combustion Engines," by R. A. Collins.

We feel sure that a " live " centre can be maintained at Bishop's Stortford.

J. P.

Bradford Centre

The very successful 1949-50 Session closed on 7th June with the Annual General Meeting. The new officers and committee took over and work on the 1950-51 Session began. The programme will include a visit to John Players Ltd., Nottingham, a Sheffield precision tool-making factory, a broadcast quiz, inspection of the Bradford Town Hall Clock tune-playing mechanism and a " Hobbies Night "—¾ in. scale steam locomotives and " 0 " gauge electric locomotives and rolling stock will be demonstrated and a film show will follow. Papers on " Ship to Shore Radio," " Transport " and" Inter-communication Systems " will be given, and it is hoped that Mr. Harbottle, the Junior Section President, will come along and address us. The committee hope to make this programme as good as, if not better than, 1949-50, and call on all past and potential members for their vigorous support. Any suggestions for visits, offers of papers, etc., will be most welcome.

A. E.

Cambridge Centre

At the Annual General Meeting held on 18th May, 1950, the following officers were elected for the 1950-51 Session :—

Chairman : L. A. Salmon ; *Vice-Chairman :* H. W. Howarth ; *Secretary :* J. P. Wearn ; *Treasurer :* B. S. Cranfield ; *Committee :* L. R. Andrews, R. M. Jones, S. J. Davis ; *Auditors :* L. W. Pooley, N. Radford.

The following are details of the programme arranged for the first half of the session :—

September, 1950.—Visit to Vauxhall Motor Factory, Luton.

October, 1950.—Return visit to University Observatories.

November, 1950.—Lecture, " Financial System of the Post Office," by Senior Section member.

December, 1950.—Local quiz.

J. P. W.

Chichester Centre

At the Annual General Meeting held on 17th May, 1950, the following officers were elected :—

Chairman : W. C. Jackson ; *Vice-Chairman :* J. A. Harrington ; *Hon. Secretary :* R. W. Smith ; *Hon. Treasurer :* A. T. Yardley ; *Hon. Auditors :* F. S. Huggett and J. R. Gillis ; *Committee :* R. E. Jenkins, D. E. Sparkes, R. D. Barrett, B. J. Ifould, F. H. Gillespie and A. V. M. Pont.

The centre has arranged a series of five lectures for the forthcoming session and one or possibly two visits to places of interest to the members. The membership has been consistently maintained at about 42 and during the previous session more than 25 per cent. attended each lecture, although A/L, sickness and other reasons have kept a few of the regulars from attending. We are looking forward to better attendances in the forthcoming session and with a full and varied programme of lectures, we hope to have catered for the greater proportion of our members.

Darlington Centre

The Conference of Representatives of the Junior Centres in the N.E. Region held at York, 15th June, 1950, is the outstanding feature since our last notes. The proposals on the agenda as enlarged upon by the respective Centre Delegates were most convincing. There was a lively exchange of views—and with the C.R.E. (Mr. W. F. Smith) Chairman, Mr. T. E. Walker, Hon. Secretary, and Mr. A. C. Holmes, Regional Liaison Officer, to guide us—many decisions were arrived at. If these can be implemented the success of the N.E. Regional Centres is assured.

Programme arrangements for the forthcoming session are well under way, and are being tackled with the spirit of the showman for " something bigger and better."

C. N. H.

Guildford Centre

The Centre was revived after its wartime temporary demise at a meeting held in February. Mr. Knox, Regional Liaison Officer, and Mr. Wells, Area Engineer, attended and promised their practical and moral support. Mr. C. W. Davies, Telephone Manager, was unable to be present but was later pleased to accept the Presidency.

The officers are as follows :—

Chairman : A. B. Biggs ; *Secretary :* F. Kelsey ; *Assistant Secretary :* L. G. Wallis ; *Treasurer :* F. B. Amery ; *Committee :* Messrs. S. Bush, Jamieson, Hill.

Progress in the early spring and summer was held up by the freak snowstorm which severely affected the Area and the Centre nearly became a casualty for the second time. However a programme of visits was arranged to Ford Motor Company, Dagenham ; Kingston New Power Station ; Friary Brewery, Guildford ; Huntley & Palmers Ltd., Reading ; Earley Power Station, Reading.

This Centre has always had certain misgivings about the title " Junior Section," feeling that outside bodies might easily gain the impression that we were a group of messenger boys or apprentices when they were asked for permission to visit them. These misgivings were realised when at the foot of the letter from the Ford Motor Company it was read : " We shall be pleased to have you visit us but we must emphasise that all visitors must be over 10 years of age " !

L. G. W.

Harrogate Centre

On 5th July a party of 30 went by coach to the works of the Jowett Car Company and spent a most interesting evening as guests of the Company, touring the various departments and seeing all branches of manufacture and assembly.

For the coming Winter Session a most comprehensive programme has been arranged, in addition to which it is hoped to have as usual one or two visits to engineering works or other places of interest in the district.

The remainder of the season's programme is as follows :—

1st November.—" Telephone Service in the Western Highlands and Isles of Scotland." Mr. J. P. Allen.

6th December.—" Banking Systems," also a Film Show. Mr. D. Johnson.

10th January.—" The 2,000-type Selector." Mr. H. Clough.

7th February.—" Outline of Television Reception." Mr. G. R. Bastow.

7th March.—" The Morris Minor Power Unit." Mr. W. Jibson.

J. T. W.

Leeds Centre

An attempt is being made to revive interest in this Centre which has been dormant since 1947. A new committee has been formed and it is hoped to prepare a programme for the coming winter of papers to be read and to arrange social evenings.

E. G. S.

Middlesbrough Centre

Thanks are due to the Editor and Officers of Junior Centres for the continued opportunities to read and digest articles of the activities of other Centres. The articles naturally vary in colour, no doubt because they cover from Southern England to Scotland and memberships from 70, or less, up to 2,500.

(*Continued on page* 164)

Notes and Comments

Birthday Honours

The Board of Editors offers its congratulations to the following members of the Engineering Department honoured by H.M. The King in the Birthday Honours List :—

Belfast Telephone Area	Pettigrew, J.	Technician Cl. I	British Empire Medal
Engineering Department	Nicholls, C. A. L.	Executive Engineer	Officer of the Order of the British Empire
London Telecomms. Region	Blake, H. G.	Technician Cl. I	British Empire Medal
London Telecomms. Region	Markwell, A. R.	Technician Cl. I	British Empire Medal
Shrewsbury Telephone Area	Bennett, C. F.	Mechanic-in-Charge, Gde. I	British Empire Medal
York Telephone Area	Markey, J. M.	Area Engineer	Member of the Order of the British Empire

Recent Awards

The Board of Editors has learnt with great pleasure of the honours recently conferred upon the following members of the Engineering Department :—

London Telecomms. Region	Ashton, G.	Technician Cl. IIA	Wt.Offr., Cl.II, R.A.C.	Member of the Order of the British Empire
Southampton Telephone Area	Hinton, M. R.	Technician Cl. IIA	Corporal, Royal Signals	Mentioned in Despatches

Mr. T. H. Flowers, M.B.E., B.Sc., M.I.E.E.

The promotion of Mr. T. H. Flowers to Staff Engineer in the Research Branch marks a step not only in his own career but also in the progress of the art and science of telephone exchange systems. Himself an expert of international repute, he has

built up and is directing a team whose present efforts may well lead to remarkable changes and improvements in the practice of the art. Such work can only be fully assessed in retrospect.

Apprenticed at the Royal Arsenal, he joined the Telephone Branch of the Engineering Department as Inspector in 1926, as a well-trained engineer but with negligible experience of telecommunications. After promotion to Assistant Engineer he was posted to the Research Branch in 1930, where he advanced to Executive Engineer in 1937, and to Assistant Staff Engineer in 1943, graduating with first-class honours in 1933.

During his earlier years in the Research Branch he designed the Post Office 2 V.F. signalling system, and throughout his service in the Post Office he has been engaged on problems connected with telephone signalling and switching, or on work of an allied nature. The alternative refers in particular to special work done during the war, the quality of which has been properly recognised by the authorities concerned and for which in 1943 he was awarded the M.B.E.

Undoubtedly, chance played a large part in deciding the nature of the work first undertaken by Mr. Flowers for the Post Office. Thereafter, his innate genius for dealing with the complexity of telephone exchange problems, and his quiet but stubborn refusal to let whatever problem was presented get the better of him, have conspired to concentrate his activities on this particular field of work. Viewed broadly, the field is a large one and presents ample scope ; his friends and colleagues wish him continued success in it.

W. W.

Publication Delay

Because of a recent dispute in the printing trade the publication of this issue of the Journal has been considerably delayed and we regret any inconvenience to readers which this delay may have caused. A further result of the difficulties has been the necessity on this occasion to reduce the amount of text. While it is hoped that more favourable conditions will apply to the January, 1951, and subsequent issues, we ask for our readers' indulgence pending a return to normal conditions in the printing trade.

Regional Notes

South-Western Region

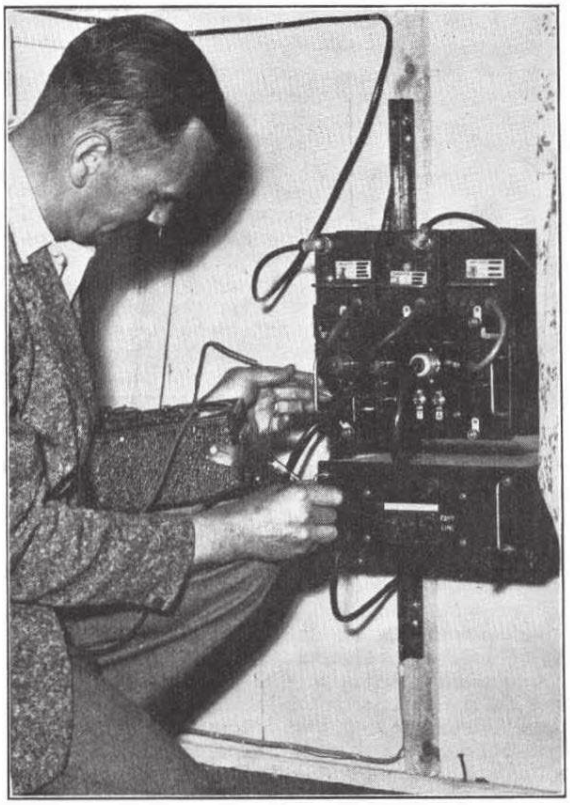
GUERNSEY-HERM RADIO LINK

An interesting installation carried out recently in the South-Western Region was the introduction of a single-channel V.H.F. radio link working from the island of Herm into the telephone network of Guernsey, Channel Islands.

Herm is a small island situated about five miles from Guernsey and eleven miles from the coast of Normandy. It has a normal population of 35, but this is greatly increased during the summer months by guests at the island's only hotel and by large numbers of day visitors who arrive from the other islands.

In January of this year urgent representations were made to Headquarters by the Guernsey Administration for the provision of communication facilities—if possible by the early part of June—and the Radio Group of the South-Western Region were asked by Headquarters to undertake the engineering, construction and installation of a radio link. The only apparatus which was readily available consisted of 12-V battery-operated mobile type equipment. It was, however, desirable to operate the circuit continuously and modifications were therefore carried out to allow A.C. mains operation, the Herm terminal working via D.C./A.C. convertors driven from the island's 200-V D.C. supply. Three power packs had to be constructed for each terminal, supplying respectively the receiver, transmitter and modulator.

Modifications to the apparatus involved the replacement of the receiver output transformer and the modulator input transformer in order to present 600 ohms to line. The conversion from D.C. operation to A.C. working also involved alteration of the bias arrangements and to the A.V.C. system.



THE TRANSMITTER AND RECEIVER UNIT AT HERM.

The receivers are crystal-controlled superheterodyne type whilst the transmitters, also crystal controlled, have output power of 7 W.

The whole of the apparatus has been built into a rack 12 in. × 12 in. × 15 in. which contains the receiver, transmitter, modulator, associated power packs and the line termination units.

The Herm terminal is installed at Foxglove Cottage, from where the 2-wire end is taken to the small magneto switchboard which at present has only two extensions. At Guernsey the apparatus is installed at Fort George radio station, the 2-wire end then being taken to the trunk positions of the States exchange. Signalling is provided by means of voice-operated relays—Unit Signalling No. 5—at either 2-wire terminal.

The aerial systems consist of dipoles with reflectors, and are connected to the equipment by co-axial cables. The two aerials at each terminal are mounted on a single 40-ft. pole.

The work of installation was carried out by Regional Headquarters' staff with assistance from the Bournemouth area. One interesting point is that the foreman in charge of the gang which performed the aerial erection last visited Herm during the recent war as a Commando sergeant—his object was looking for any radio stations which he had instructions to wreck. This temporary equipment has proved very successful and reliable since installation. It will be replaced in due course by a production model of the standard island installation, the prototype of which is under trial in the Welsh and Border Counties Region.*

Welsh and Border Counties Region

POLE DAMAGE BY LEAF-CUTTER BEE

Progress with the pole-testing programme is well advanced in this Area, but an interesting find was made in a pole on a route which had not yet been reached by the testing parties.

On report of a fault on the only circuit carried by a route of light poles, the linesman found one pole leaning over and fractured several feet above ground level. The pole was renewed the next day, and when it was allowed to fall it split along its length, revealing a number of smooth round tunnels running lengthways with the grain. The pole was an old light pole and was decayed downwards from the head for some 6 ft. The route is alongside a very quiet road and there are many birch trees near.

A solitary bee was noticed to be taking an interest in the newly erected replacing pole, and after a short time it alighted on the broken split pole lying on the ground. An attempt to catch the bee failed. Lying in the channels cut in the decayed portion of the pole were a number of cells and pieces of leaf, still green and recognisable as pieces of birch leaf.

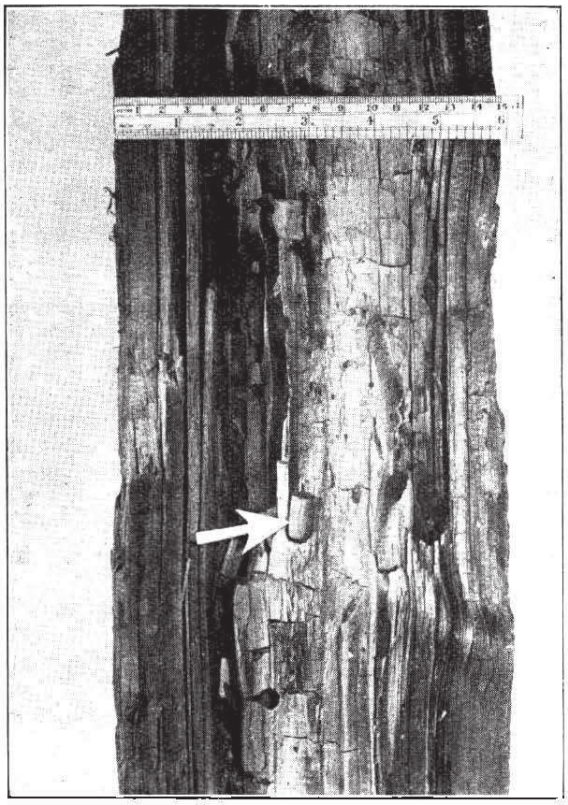
On examination of the completed cells, which are hollow, thimble-like structures, it was evident that a craftsman insect had been at work. Reference to local Field Society entomologists resulted in the work being recognised as that of the leaf-cutter bee, one of the most interesting of the solitary bees. It is of the family *Megachilidæ*, which includes the leaf-cutter and mason bees and their allies. It is familiar to many people who grow roses, on account of its habit of cutting out neat smooth-edged pieces from the leaves and petals of this plant. The cutting process is carried out with a precision which suggests the work of a machine.

The tunnelling is carried out in a decaying post or

* *P.O.E.E.J.*, Vol. 43, April 1950, p. 52.

worm-out woodwork, and the tunnels may extend considerably more than a foot.

The brood cells are made entirely of layers of excised pieces of leaves or flower petals, and are shaped like thimbles. In each cell the female places a supply of paste of pollen and honey, and lays an egg. The end of the cell is sealed by a circular piece of leaf or petal



PORTION OF DAMAGED POLE WITH CELL OF LEAF-CUTTER BEE INDICATED BY ARROW.

and this "thimble" is then the home of the grub and pupa until it is ready to emerge as a bee.

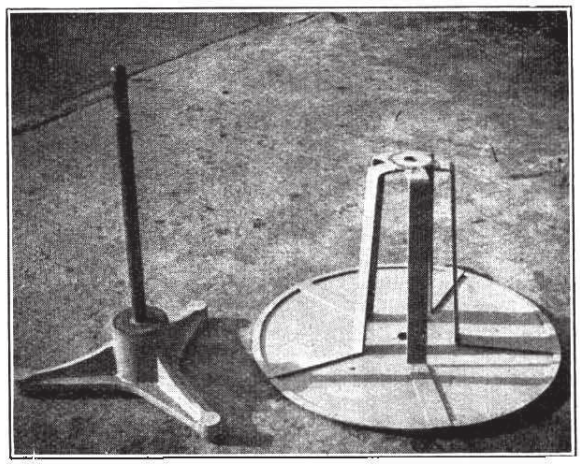
Although the bee is not large, being about the size of a small domestic bee, it is evidently a hard worker capable of weakening an already affected pole to a dangerous extent. S. H. P.

CABLE SWIFTS FOR EXCHANGE CONSTRUCTION WORKS

During the past two years a considerable amount of exchange construction work has been undertaken by departmental labour in this Region including the installation of several complete C.B.10 exchanges. The need for a cable swift, which has been felt for a number of years, was therefore increased and it was decided to manufacture a number in the Regional Workshops. The requirements of the swift to meet the conditions of exchange construction work were considered to be :—

(1) It should be sturdy so as to stand rough handling during transport.
(2) It should be suitable for holding coils of switchboard cable of various sizes.
(3) It should run freely enough for a cable to be taken off with a reasonable pull, but not to over-run.
(4) Its weight should be such that it would not drag along the floor when in use.

The first swift made had a conical centre of sheet metal which was found to be difficult to construct with facilities available. It also had a ball bearing which resulted in over-running. In the final construction



CABLE SWIFT CONSTRUCTED IN WELSH AND BORDER COUNTIES REGION.

therefore a slatted centre has been used and the ball bearing substituted by a solid thrust bearing. The base of the original model was made of angle iron welded to the central bearing support but subsequently arrangements were made for the bases to be cast by a local firm.

Reports so far received show that the swifts meet the conditions specified and are satisfactory in every way. They are proving a useful addition to the exchange construction parties' kit. S. E. N.

North-Western Region

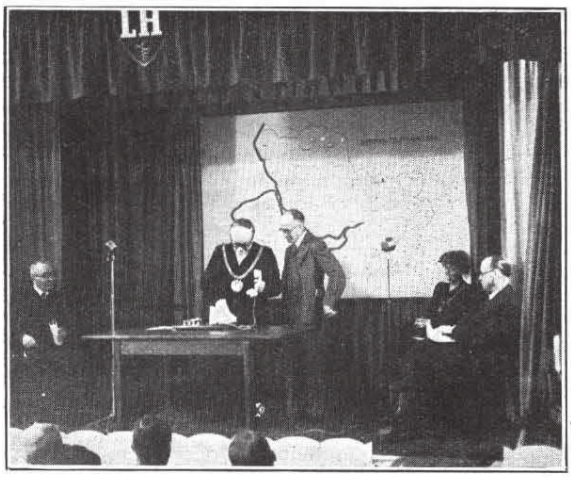
"TIM" COMES TO MERSEYSIDE

Although a speaking clock was brought into service in Lancaster House, Liverpool, in 1942 for supplying the "TIM" service for the north of the country and also to act as a reserve in the event of the failure of the London clock, the service has not been available to the Liverpool Telephone Area because of a shortage of the local supply equipment. However, some spare equipment recently became available and after it had been completely renovated and rebuilt by the local construction staff, it was decided that the Liverpool Area should enjoy the facility that they had been supplying to other Areas. It was considered that some publicity for the new facility was justified and accordingly an invitation to perform the opening ceremony was extended to and kindly accepted by the Lord Mayor of Liverpool.

The ceremony was conducted on a stage owned by members of the Lancaster House Canteen Club, and as shown in the illustration a large map of the Liverpool Telephone Area was erected at the back of the stage. Each exchange was indicated by a supervisory lamp opal underneath which was a label showing the exchange name. The director exchanges on the map, that is, those exchanges that could dial "TIM," were indicated by red opals, the remaining exchanges in the unit fee area for a "TIM" call were indicated by white opals and all other exchanges had green opals. The supervisory lamps were wired to a chromium-plated switch mounted on a polished baseboard which was placed on a table on the stage. An ivory telephone connected as an exchange line was also mounted on the baseboard. In addition, an amplifier and loudspeakers were connected to the telephone circuit.

The routing of "TIM" calls from the various director automatic exchanges to the speaking clock is via the Tandem exchange. Therefore, after the director translations for "TIM" had been completed, all that was necessary to bring the service into use was to open the tandem level to the speaking clock relay sets. The signal for this operation was also controlled by the switch mentioned above.

At the opening ceremony on Monday, 10th July, 1950, the Telephone Manager made an introductory speech and then invited the Lord Mayor to open the "TIM" service by operating the switch, followed by the dialling of "TIM" on the telephone.



INAUGURATION OF "TIM" SERVICE IN LIVERPOOL BY THE LORD MAYOR.

The Lord Mayor in his speech stated that he was considered to be a "Jonah" at these ceremonies; but in spite of this remark when he closed the switch the map became illuminated by all the supervisory lamps indicating the exchanges having access to "TIM" and his call to "TIM" was received by the audience through the loudspeakers at 11.35 a.m.

From left to right in the photograph are the Head Postmaster (Colonel R. E. Evans, C.B.E., T.D.), the Lord Mayor of Liverpool (Alderman the Rev. H. D. Longbottom), the Telephone Manager (Mr. H. C. Jones, O.B.E., M.I.E.E.), the Lady Mayoress, and the Deputy Regional Director (Mr. H. A. Ashton).

After the ceremony, the Mayoral party toured Lancaster House and were then entertained to lunch. During the lunch the Lord Mayor was presented with an album containing photographs of various items of interest in Lancaster House. Included in the album were photographs of the arrival of the Lord Mayor's party for the visit and one of him actually performing the opening ceremony as reproduced above. This rapid "developing and printing" service was carried out by the recently formed Area Camera Club.

To cater for the anticipated "TIM" traffic, 24 circuits were provided from tandem to the speaking clock equipment for calls originated by the director automatic exchanges. In addition, 8 overflow circuits from the tandem level were routed to the manual board. These were provided on a temporary basis to carry the initial "curiosity" traffic. Any calls originating on these circuits would be connected without challenge by the operator via manual circuits to the speaking clock. For calls originated by manual exchange subscribers 30 circuits were provided to the speaking clock.

For the three days following the opening of the service an average of 7,800 calls per day were made from the director exchanges and 1,945 were made from the manual exchanges. The volume of traffic was such that the tandem overflow circuits were not required, and steps were also taken to reduce the manual exchange circuits. A further safeguard taken during the initial stages was the reduction of the time pulse throw-out from 90 seconds to 36 seconds on the speaking clock relay sets. After a few days it was found that this could be restored to the normal 90 seconds. H. G. C.

London Telecommunications Region

LONDON AIRPORT P.B.X.

The telephone requirements of London Airport are at present provided by a P.M.B.X. 1A installation, but in 1952 the Airport territory is to be given the status of a public exchange and served by a non-director automatic exchange. It became apparent, however, that the Airport requirements would far exceed the capacity of a P.M.B.X. 1A equipment before the conversion to automatic working. The two obvious solutions have been either the installation of an additional P.M.B.X. 1A unit with transfer working or the complete replacement by B.E.C.B. 10 equipment. The former would be undesirable and costly from an operating point of view, while the capital cost of the latter could not be justified for so short a life. The required capacity has been obtained therefore by non-standard rearrangement of the existing P.M.B.X. 1A equipment.

In a normal fully equipped P.M.B.X. 1A installation, some 40 per cent. of the face of the switchboard is occupied by spacing strips, this being the positions where calling lamps are not required. The rearrangement adopted has aimed at making use of this space, and does not involve any departure from standard circuits.

The calling lamps are removed from their physical association with the jacks which they serve, and are concentrated in the lowest three positions which are reserved for this purpose. Strips of ten lamps for exchange lines and private wires or of 20 for extensions or spacing strips are provided in these three positions, as called for in the traffic data. Above these the multiple jacks are fitted close in formation, that is, without any spacing strips. In the present case the estimated ultimate requirements for 320 exchange lines and private wires are being provided with 23 positions. The maximum number of extensions is of the order of 1,500, equipment being provided at present for 1,200.

A small frame is fitted near the growing end of the suite, on which are terminated :—

(i) All the calling lamps.
(ii) The lamp feeds for the exchange lines and private wires, which are cabled direct from the apparatus racks.
(iii) The B line tails for the extension multiple.
(iv) Long-line relays.

Thus, any strip of lamps may be associated with any group of jacks (so far as they are strips of ten or twenty), and a calling relay may easily be jumpered into any circuit. Due to the physical size of the Airport, a larger number of relays than normal is required, and these are strip-mounted away from the racks.

Operators identify each strip of lamps with the jacks which they serve by means of coloured markings on the stile strips, and no difficulty in operating seems to have been experienced. It should be noted that a strip of lamps is only associated with jacks which have appearance on the same panel, and only in complete strips.

The work, up to the time of writing, is still in progress, but the most difficult phase, the rearrangement of the existing suite while on traffic, has been completed with

surprisingly little inconvenience to the Airport authorities. A considerable amount of work was performed at night, when the traffic was at its lowest. The multiple cabling is somewhat congested, and may give rise to maintenance troubles, but fortunately the life of the equipment is to be very short. The accommodation of the lamp cables in the suite set a problem, but these difficulties have been satisfactorily overcome. A. B. C.

Midland Region

USE OF MOBILE BORER AND POLE LIFTER

Under the programme of trunk recovery in the Birmingham Area, a large number of stout poles was included in the schedule. Where a line of poles existed in situations free from serious obstacles, use has been made of a combined borer and lifter, the property of the British Electricity Authority. It consists of a derrick and earth auger; both are mounted on a lorry chassis with a 50-h.p. power unit and operated by the lorry engine through a separate gear box. The auger can be changed according to the size of hole required and has been used on previous occasions with considerable success in the erection of poles. The derrick only has been used in recovery work, and is fitted with horizontal arms near the base to prevent poles from swinging when lifted.

POLE DRAWN JUST CLEAR OF GROUND.

The method of use is to back the vehicle up to the pole to be recovered, and make off the steel rope to the pole above the point of balance. The winch is then started and the pole is drawn vertically out of the ground. When clear of the ground the pole is lowered on to a transport vehicle, for removal to a temporary stack for ultimate disposal or re-use.

The borer and lifter which is hired by the day from the B.E.A., is capable of extracting poles up to 50 ft. long. It has been necessary to cut off the tops of poles taller than 50 ft. and also to strip poles of arms, etc., to avoid the fittings fouling the lattice of the derrick as the pole rises.

The saving in time and labour by this means can be estimated by the fact that in reasonable weather conditions and on a grass verge of moderate width, 32 stout poles have been removed and placed on the pole stack in one day. E. G. H.

Home Counties Region

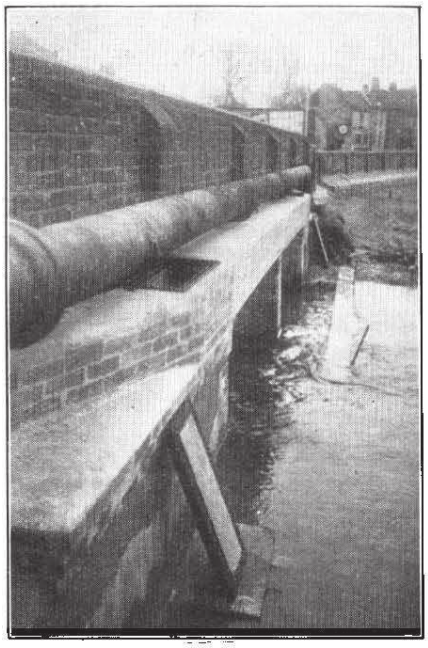
A BRIDGE-CROSSING EXPEDIENT

The metal conduits attached to the outside of Hermitage Bridge, Emsworth, carried a large number of trunk and junction circuits across an inland water creek; but salt water corrosion had disintegrated the pipes leaving only the thick socket ends supported by the cables. It was decided, therefore, to replace the conduits with a reinforced concrete trough fitted with removable covers, the trough to be carried on brickwork projections on the bridge piers. Proposals were submitted to and approved by the Highway Authority, subject to the condition that the new structure did not impair the appearance of the bridge.

Work was commenced by stripping from the cables what remained of the metal conduits; this was not difficult in the portions that had been exposed to the action of the salt water. It had been decided to extend the trough through the bridge parapet to the carriageway and cut away the steel conduits to the joint boxes at each end of the bridge. The steels were cut with an electric "Skilsaw," power being provided by an emergency charging set. After the metal conduits had been removed the cables were examined and pressure-tested.

Extensive timbering was necessary in forming the troughs, none of which was fastened to the fabric of the bridge—the whole of the moulds being carried on struts wedged between the bridge piers. To meet the Highway Authority's request for stronger reinforcement in the carriageway, ½ in. steel plates were cut to fit over the trough leaving half the width of the trough wall for "knitting" to a final covering of reinforced concrete. As this proved successful it was decided to plate and concrete the whole of the trough instead of fitting removable covers. A small frame and cover was built into the roof of the trough for cabling purposes on each side of the creek on the outside of the bridge walls.

The waters are tidal and often in the morning the work was found festooned with seaweed and other refuse of backwater creeks.



REINFORCED CONCRETE TROUGH PROVIDED ON HERMITAGE BRIDGE, EMSWORTH.

The advantages gained by the expedient were that the bridge road surface was only disturbed at the solid ends where the trough was led into the joint boxes, the road over the bridge archways being left undisturbed. The extensive cabling operations that would have been necessary in renewing the conduits were avoided. The dimensions of the trough were made ample to cover all future cabling requirements. T. A. M.

AN UNUSUAL MOLE-DRAINING EXPERIMENT

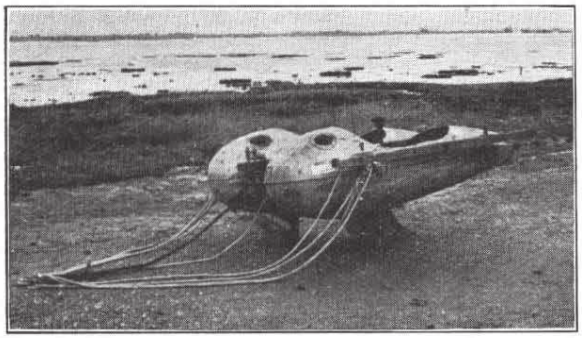
Horsey Island is situated to the North West of the town of Walton-on-the-Naze, Essex, and is separated from the mainland by Hamford Water on the North and Kirby Creek and the Wade on the South. The only approach other than by boat is across a causeway over the Wade.

This causeway is some ¾ mile in length and 6 ft. to 8 ft. in width. It is an ancient construction consisting of boulders and shingle and capable of carrying a heavy lorry. The whole causeway is covered at high tide to a depth of 6 ft. to 9 ft. when the channel is used by various craft.

The Island is farm land, there being one farmhouse and outbuildings, and when towards the end of 1949 the question of telephone installation came up for consideration problems arose.

Overhead construction was obviously unsuitable along the causeway as it would cause an obstruction to craft using the fairway. The causeway itself was unsuitable for trenching owing to its narrow width and the short periods during which it was above water and also the impossibility of reinstatement to anything like its original consolidation. It was bounded on each side, except for a few small creeks, by extensive areas of soft mud, and the possiblity of laying a cable in this by a system of mole-draining was considered.

Although this mud was much too soft for the use of normal mole-draining equipment the idea of a mole-draining raft was considered to be practicable. Thoughts turned to some old American Air Force auxiliary petrol tanks, a number of which were lying on a nearby aerodrome. Two were obtained, braced together



THE MOLE DRAINING RAFT, SHOWING STEERING TACKLE AND CENTRE PLATE.

with old eight-way arms and fitted with a centre plate 2 ft. 6 in. by 1 ft. 3 in. by ⅝ in., and a ¾ in. pipe was welded to the rear of the plate to take the cable but it was left without a mole, this not being necessary in the soft mud.

Steering was arranged with one centre tow rope fixed to sets of double block and tackle, one to each side, so that a towing pull could be varied and a steering effect obtained, this being necessary to keep the mole-draining raft several feet away from the causeway while working parallel with it.

The use of the causeway being limited to approximately four hours per day for normal tides and varying with low tides, it was not until February 14th, 1950, when the weather and tides proved suitable for a test, that the scheme was proved to be practicable.

In consultation with the Engineer-in-Chief's Office it was decided to use 1-pair polythene cable and also to mole-drain the parts along the approach roads on both sides of the causeway thus avoiding the use of overhead construction altogether.

Conditions again proved suitable on April 12th for work on the mudflats and two 1-pair cables were laid across the creek, one run being made in each direction. The raft was towed by a 30-cwt. W.D. type lorry running along the causeway 250 yards ahead, the cable being paid out from a second lorry running parallel with the mole-drainer raft. The steering of the raft was controlled by one man who sat on the raft and who also dealt with the removal of stray obstructions which became wedged across the blade at times.

CROSSING A SMALL CREEK. CABLE CAN BE SEEN ENTERING TUBE BELOW DRIVER'S RIGHT ARM.

Some trouble was expected from thick growths of marram grass, but surprisingly enough this did not occur as the blade cut through easily. The raft crossed the small gulleys with little difficulty, but in two creeks there was too much water for the blade to reach the bottom and the raft floated over without burying the cable in the mud and some slack had to be left to enable the cable to be buried by hand at the next spring tides.

The cable, being obtainable in half-mile lengths only, had to be jointed and this was carried out after the laying operations by polythene cable experts from the Engineer-in-Chief's Construction Branch. Two special mechanical joints were also provided between the land and submarine sections for assistance if any trouble should arise in the cable under the water and these were fitted on the cable warning beacon poles which had been erected previously.

An infinity reading with a 500-V megger was obtained on each cable after the operations, the circuit was completed and working the next afternoon, and up to the time of writing no trouble of any kind had developed.

Staff Changes

Promotions

Name	Region	Date
Deputy C.R.E. to Staff Engr.		
Moffatt, C. E.	L.T. Reg. to E.-in-C.O.	1.7.50
Asst. Staff Engr. to Staff Engr.		
Flowers, T. H.	E.-in-C.O.	1.7.50
Regl. Engr. to Deputy C.R.E.		
Stratton, J.	Mid. Reg. to L.T. Reg.	23.7.50
Exec. Engr. to Asst. Staff Engr.		
Bray, W. J.	E.-in-C.O.	5.6.50
Balcombe, J.	H.C. Reg. to E.-in-C.O.	18.6.50
Davison, G. N.	E.-in-C.O.	16.7.50
Area Engr. to Deputy T.M.		
Gill, F. W.	L.T. Reg.	18.7.50
Exec. Engr. to Principal		
Armstrong, R. G.	E.-in-C.O. to P. & A. Dept.	10.7.50
Fryer, P. W. F.	E.-in-C.O. to A. & P. R. Dept.	16.7.50
Engr. to Exec. Engr.		
Birnie, R. C.	Scot.	31.5.50
Harris, E. T. C.	E.-in-C.O.	28.5.50
Pilling, T.	E.-in-C.O.	28.5.50
Richards, D. L.	E.-in-C.O.	22.6.50
Goodwin, A. E.	E.-in-C.O.	14.7.50
Goford, R.	H.C. Reg.	14.7.50
Corke, R. L.	E.-in-C.O.	12.7.50
Jowett, J. K. S.	E.-in-C.O.	16.7.50
Davies, R. C.	E.-in-C.O.	12.7.50
Jones, D. G.	E.-in-C.O.	30.7.50
Reynolds, J.	E.-in-C.O.	1.8.50
Engr. to Sen. Sc. Offr.		
Hill, L. W.	E.-in-C.O.	19.5.50
Prob. Engr. to Engr.		
Castellano, E. J.	L.P. Reg.	1.5.50
Eley, A. C.	Mid. Reg.	6.5.50
Coustick, E. A. R.	Mid. Reg.	6.5.50
Meredith, T. E.	E.-in-C.O.	14.6.50
Mitchell, G.	E.-in-C.O.	14.6.50
Low, A. T.	E.-in-C.O.	1.6.50
Rymer, N. B.	E.-in-C.O.	14.6.50
Smith, P. E.	E.-in-C.O.	27.6.50
Abbott, P. W.	E.-in-C.O.	1.6.50
Walker, J. D.	L.T. Reg.	7.6.50
Carnson, L. B.	L.T. Reg.	1.6.50
Barker, A. J.	L.T. Reg.	28.6.50
Colyer, J. O.	L.T. Reg.	7.6.50
Seamans, K. R.	H.C. Reg.	28.6.50
Francis, R. S.	H.C. Reg.	28.6.50
Morton, J. Y.	E.-in-C.O.	17.7.50
Bennett, R. O.	E.-in-C.O.	4.7.50
Horne, F. A.	E.-in-C.O.	4.7.50
Kitchen, R. G.	E.-in-C.O.	17.7.50
Berresford, B. H.	E.-in-C.O.	1.6.50
Croft, E.	L.T. Reg.	1.7.50
Feere, S. E.	E.-in-C.O.	1.8.50
Asst. Engr. to Engr.		
Duncan, N.	Scot. to E.-in-C.O.	20.5.50
Hulcoop, G. J.	H.C. Reg.	1.6.50
Bett, H.	H.C. Reg.	2.5.50
Piggott, T. W.	S.W. Reg.	2.5.50
Chapman, B. E. J.	L.T. Reg. to Scot.	30.5.50
Cooper, E. B.	E.-in-C.O. to L.T. Reg.	17.6.50
Mead, A. C.	L.T. Reg.	14.6.50
McEacham, J.	Scot.	14.6.50
Hills, G. W. P.	H.C. Reg. to Scot.	24.6.50
Ratcliffe, K. S.	E.-in-C.O.	14.6.50
Hales, J. R.	E.-in-C.O.	14.6.50
Beck, E. H. A.	E.-in-C.O.	14.6.50
Felton, N. F.	E.-in-C.O.	14.6.50
Nicholls, P. A.	E.-in-C.O.	14.6.50
Ashwell, J. W. G.	L.P. Reg.	14.6.50
Smith, G. H.	L.T. Reg.	1.7.50
Eustace, J.	L.T. Reg.	8.7.50
Tech. Offr. to Asst. Engr.		
Swift, F. H.	E.-in-C.O.	24.6.50
Sinclair, A. D.	E.-in-C.O.	4.7.50
Harrison, N. G.	E.-in-C.O.	5.6.50
Dean, C.	E.-in-C.O.	22.7.50
Robinson, A. J.	E.-in-C.O.	22.7.50
M.T.O. III to M.T.O. II		
Swire, W. L.	E.-in-C.O.	10.5.50
Tech. Asst. to M.T.O. III		
Williams, S. A.	W.B.C. Reg.	10.5.50
Collings, E. R.	E.-in-C.O.	10.5.50
McConnell, D. A.	E.-in-C.O.	25.6.50
Partington, H.	E.-in-C.O.	10.5.50
Short, R.	E.-in-C.O.	10.5.50
Mech. i/c to Tech. Asst.		
Jackson, A. A. S.	W.B.C. Reg. to E.-in-C.O.	25.6.50
Mitchell, A. J.	London to E.-in-C.O.	10.5.50
Williams, C. F. H.	E.-in-C.O.	9.7.50
Chilcott, J. F.	Mid. Reg.	16.1.50
Holmes, E. C.	W.B.C. Reg.	16.1.50
Kemp, A. R.	S.W. Reg.	16.1.50
Tait, G. W.	Scot.	16.1.50
Waters, E. W.	London	16.1.50
Rutter, L. C.	H.C. Reg.	16.1.50
Maley, A. T.	Scot.	16.1.50
Norris, V. W.	London	16.1.50
Leggett, H. E.	S.W. Reg.	16.1.50
Wilson, H.	Mid. Reg.	16.1.50
Finlay, W. T.	Scot.	16.1.50
Thompson, J.	N.E. Reg.	16.1.50
Whitehead, R. H. J.	N.E. Reg.	16.1.50
Booth, A. W.	H.C. Reg.	16.1.50
Byatt, H. A.	E.-in-C.O.	19.7.50
Hicks, A. P.	E.-in-C.O.	19.7.50

Transfers

Name	Region	Date
Exec. Engr.		
Ackroyd, J. O.	E.-in-C.O. to Admiralty	1.6.50
Engineer		
Davies, R. C.	N.W. Reg. to E.-in-C.O.	9.7.50
Asst. Engr.		
Seabrooke, G. A.	E.-in-C.O. to Inland Revenue	1.6.50
Mitchell, S. F.	E.-in-C.O. to Min. of Supply	1.6.50
Terrington, D. G.	E.-in-C.O. to Min. of Civil Aviation	1.6.50
Asst. Engr.—continued		
Franklin, L. E.	E.-in-C.O. to Mid. Reg.	1.6.50
Stollard, A. F.	E.-in-C.O. to Mid. Reg.	8.8.50
Woodford, R. A.	E.-in-C.O. to Min. of Supply	1.8.50
Gardner, D. H.	E.-in-C.O. to H.C. Reg.	14.8.50
Williams, E.	W.B.C. Reg. to S.W. Reg.	12.9.49
Lindsey, G. F.	H.C. Reg. to E.-in-C.O.	14.8.50
Asst. Exptl. Offr.		
Pidgeon, D. J.	E.-in-C.O. to Min. of Supply	3.7.50

Retirements

Name	Region	Date
Staff Engr.		
Frost, P. B.	E.-in-C.O.	30.6.50
Asst. Engr.		
Mallows, E. G.	L.T. Reg.	15.6.50
Hales, G. A.	N.W. Reg.	30.6.50
Thorley, C. B.	Mid. Reg.	23.6.50
Butler, L. H.	E.-in-C.●. (Resigned)	29.5.50
Greenwood, G. F.	L.T. Reg.	31.7.50
Mitchell, E.	E.-in-C.O. (Resigned)	30.6.50
Robinson, J. G.	N.W. Reg.	26.8.50
Burgess, H. P.	L.T. Reg.	30.6.50
Bale, W. F.	L.T. Reg.	31.7.50
Brockwell, A. H.	L.T. Reg.	27.7.50
Kendall, C. A.	N.W. Reg.	31.8.50
Swann, G. E.	L.T. Reg.	31.8.50
Soar, W. D.	E.-in-C.O.	31.7.50
Gaukroger, W.	N.E. Reg.	14.6.50
Harding, C. C.	W.B.C. Reg.	20.5.50
Stead, A. D.	H.C. Reg.	16.1.50
Grigg, C. E.	Mid. Reg.	20.8.50
Hicks, C. J.	L.P. Reg.	10.4.50
Thomson, J.	Scot.	14.8.50
Peter, D. T.	Scot.	31.7.50
Phipps, G. R.	L.T. Reg.	31.8.50
Inspector		
Gosling, S. E.	L.T. Reg.	30.6.50
Dewhurst, A. J.	L.T. Reg.	17.7.50
Lightbown, A.	N.W. Reg.	25.7.50
Taylor, T.	N.E. Reg.	23.6.50
Bentley, R. H.	N.E. Reg.	21.3.50
Marks, J. S.	W.B.C. Reg.	29.4.50
Leney, H.	H.C. Reg.	31.3.50
Lilleywhite, G. S.	H.C. Reg.	31.5.50
Twort, H. S.	H.C. Reg.	6.2.50
Hayes, R. G.	H.C. Reg.	15.3.50
Hurst, S. A.	H.C. Reg.	12.6.50
Gallagher, P.	N.I.Reg. (Resigned)	13.2.50
Wonson, F. J.	S.W. Reg.	16.6.50
Wright, A. R. T.	S.W. Reg.	30.6.50
Stewart, H.	Scot.	18.2.50
Martin, F.	Scot.	28.4.50
Richards, J.	S.W. Reg. (Resigned)	28.2.50
Gosney, P. A.	L.T. Reg.	18.3.50
Vickerage, H. B.	L.T. Reg.	11.4.50
Glendening, C. G.	L.P. Reg.	16.1.50
Sharp, A. F.	L.P. Reg.	28.3.50

Deaths

Name	Region	Date
Engineer		
Thompson, J. G.	N.E. Reg.	25.7.50
Asst. Engr.		
Harrington, W. E.	L.T. Reg.	1.6.50
Fox, J.	N.E. Reg.	23.6.50
Nokes, H. R.	L.T. Reg.	27.7.50
Asst. Engr.—continued		
Gould, C. C.	W.B.C. Reg.	19.3.50
Rogerson, T.	N.W. Reg.	8.8.50
Randle, F.	Mid. Reg.	4.8.50
Inspector		
Edwards, E.	Mid. Reg.	27.6.50

CLERICAL GRADES

Promotions

Name	Region	Date
E.O. to H.E.O.		
Magness, W. H.	E.-in-C.O.	20.2.50
C.O. to E.O.		
Crook, J.	E.-in-C.O.	4.6.50
Wallis, W. G.	E.-in-C.O.	1.7.50

Retirements

Name	Region	Date
E.O.		
Clarke, E. V.	E.-in-C.O.	30.6.50

JUNIOR SECTION NOTES

(*Continued from page* 155)

May we appeal to all to take a lively interest in the Junior Section and their colleagues so that men become persons to each other—whatever their job is—and thus achieve the success desired. Whilst a large membership and strong financial position have been ensured by the payment of subscriptions by deduction from pay, we would like to see a larger percentage of members at the meetings in the coming winter.

Your officers are now completing the final arrangements of the programme for the forthcoming 1950-51 Session. In addition to other interesting items, we are pleased to report that three of our members have agreed to give lectures. Congratulations to those members of other Centres who have been awarded prizes in the Essay Competition. J. B.

Portsmouth Centre

We are looking forward in 1950-51 Session to another successful programme, the events planned being four film shows (sound) and the following lectures :—

(1) " Trunk Mechanisation and the Cordless Switchboard," by our Telephone Manager, Mr. H. C. Andrews.

(2) A reserved subject, to be given by our Area Engineer, Mr. R. Goford.

(3) " Sound Recording," by Mr. Baker.

Our proposed visits are as follows :—

(1) Visit to a submarine, though the Navy will not allow us to " sink."

(2) A conducted tour of an aircraft carrier.

(3) The Pirelli Cable Works, Eastleigh.

(4) British Oxygen Company.

(5) Messrs. Guinness, Park Royal.

Our membership now totals about 170, which makes an increase of about 45 members in a year. If we could get that increase at our meetings, then we should feel inclined to challenge any Section in the country.

Nevertheless we are proud to say Portsmouth Centre is very much alive and working in the right direction. W. F.

Scarborough Centre

The Annual General Meeting was held on 11th May, 1950, when a successful year's working was reviewed.

As the Chairman, Treasurer and Secretary had announced their intention of retiring after the 1949-50 Session it was the wish of the Centre that it be placed on record that the retiring officers—Messrs. F. Cowper, A. B. Clarke and P. Mitton—be accorded a hearty vote of thanks for their 13 years' continuous service as officers of the Centre. A fine example to the Institution and the Scarborough Centre in particular had been set by these officers over a long period, and the incoming officers and committee are resolved to do their best to maintain the spirit and continue the good work.

The following officers were elected for the 1950-51 Session :—

Chairman : D. S. Stephenson ; *Treasurer :* J. E. Wiseman ; *Secretary :* A. S. Bryce ; *Social Organiser :* K. Megginson ; *Committee :* A. L. Theasby, F. Cowper, G. M. Archer, P. L. Mitton, A. B. Clarke, G. Cordukes, J. Dale, H. Birch, M. Rawlinson, D. Owen, E. Horsman, B. Leadlay, D. Kynman. S. S.

Tunbridge Wells Centre

A very successful series of meetings was held during the season 1949-50. It was gratifying to see so many members at each meeting and it is hoped that the interest will be maintained during the forthcoming season. The Branch is now on a very firm basis both in membership and financially.

Our final venture of the season, a coach trip to Fulham Power Station, was one of the most interesting of our visits, our only regret being that more of our colleagues could not join us. A. E. C.

BOARD OF EDITORS

H. FAULKNER, C.M.G., B.Sc., M.I.E.E., Chairman.
F. E. NANCARROW, O.B.E., A.R.C.Sc., M.I.E.E.
A. H. MUMFORD, O.B.E., B.Sc.(ENG.), M.I.E.E.
W. T. GEMMELL, A.C.G.I.,B.Sc.,M.I.MECH.E.,A.M.I.E.E.
W. WEST, B.A., M.I.E.E.
D. A. BARRON, M.Sc., A.M.I.E.E.
A. F. STOLLARD.
C. E. MOFFATT, A.C.G.I., WH. EX., A.M.I.E.E.
G. E. STYLES, A.M.I.E.E., Managing Editor.
W. A. HUMPHRIES, A.M.I.E.E.
J. P. HARDING, B.Sc.(ENG.), A.M.INST.C.E., A.M.I.E.E. } Assistant Editors.
A. J. HUTCHINSON, Secretary-Treasurer.

Copyright

The entire contents of this JOURNAL are covered by general copyright, and special permission is necessary for reprinting long extracts, but Editors are welcome to use not more than one-third of any article, provided credit is given at the beginning or end thus : "From the *Post Office Electrical Engineers' Journal.*"

The Board of Editors is not responsible for the statements made or the opinions expressed in any of the articles in this JOURNAL, unless such statement is made specifically by the Board.

Communications

All communications should be addressed to the Managing Editor, *P.O.E.E. Journal,* Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Telephone : HEAdquarters 1234. Remittances should be made payable to " *The P.O.E.E. Journal*" and should be crossed "& Co."

Binding Cases

Cases for binding are available, and may be obtained from the Local Agents for 2s. Subscribers can have their copies of Volumes bound, at a cost of 7s. 6d., by sending the complete set of parts to the Local Agents or to the *P.O.E.E. Journal,* Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Orders for binding for Vols. 1-19 should indicate whether the original binding case with black lettering, or the later pattern with gold, is required. Cases with gold lettering are the only type stocked from Vol. 20 onwards.

Back Numbers

The price of the JOURNAL, which is published quarterly, is 1s. 6d. (1s. 9d. post free) per copy, or 7s. per annum post free. Back numbers can be supplied, subject to availability of stocks, at 1s. 6d. each (1s. 9d. post free). Orders for back numbers may be sent to the Local Agents or to the Publishers.

Advertisements

All communications relating to space reservations should be addressed to the Advertisement Editor, *P.O.E.E. Journal,* Alder House, Aldersgate Street, London, E.C.1. Communications regarding advertisement copy, proofs, etc., should be addressed to the Publishers, Messrs. Birch & Whittington (Prop. Dorling & Co. [Epsom], Ltd.), 49 Upper High Street, Epsom, Surrey.

MODEL ANSWERS

TO

CITY AND GUILDS OF LONDON INSTITUTE EXAMINATIONS

Students preparing for City and Guilds examinations in Telecommunications will find the Model Answers published in book form a useful aid to study. The questions and answers have been extracted from Supplements to the Journal issued during recent years, and, after careful revision, have been grouped under headings corresponding with the new syllabuses introduced by the City and Guilds in 1947.

Model Answers to questions which, on account of paper shortage, were unanswered in Supplements issued during the war years are also included.

The following books have been published to date :—

TELECOMMUNICATIONS (PRINCIPLES) I — **TELECOMMUNICATIONS (PRINCIPLES) II**

RADIO I — **TELEGRAPHY I**

TELEPHONE EXCHANGE SYSTEMS I — **TELEPHONE EXCHANGE SYSTEMS II**

(PRICE 2/6 EACH POST FREE, 2/9)

TELEGRAPHY II

(PRICE 3/6 POST FREE, 3/9)

Orders may be placed with the JOURNAL LOCAL AGENTS or with THE MANAGING EDITOR, POST OFFICE ELECTRICAL ENGINEERS' JOURNAL, ALDER HOUSE, ALDERSGATE STREET, LONDON, E.C.1

In course of preparation. Publication dates and prices to be announced later :

RADIO II — **LINE TRANSMISSION I**

INDEX TO ADVERTISERS

Alton Battery Co., Ltd., The x
Automatic Coil Winder & Electrical Equipment Co., Ltd. xvii
Automatic Telephone & Electric Co., Ltd. .. viii, ix
British Institute of Engineering Technology xi
Creed & Co., Ltd. xvi
Dubilier Condenser Co. (1925) Ltd. vi
Ericsson Telephones, Ltd. xxi
Evershed & Vignoles, Ltd. xv
Ferranti, Ltd. vii
General Electric Co., Ltd., The .. .. .. xviii, xix
Great Northern Telegraph Co., Ltd. xxii
Hackbridge Cable Co., Ltd. iv
Hall Telephone Accessories, Ltd. xiii
Muirhead & Co., Ltd. vii
Neill, James, & Co., Ltd. xi
Pitman, Sir Isaac, & Sons, Ltd. iii
Siemens Brothers & Co., Ltd. xii
Standard Telephones & Cables, Ltd. .. .. .. v, xx
Sullivan, H. W., Ltd. xiii
Telephone Manufacturing Co., Ltd. xvii
Tungstone Products, Ltd. xiv
Turner, E., Electrical Instruments Ltd. iv
Westinghouse Brake & Signal Co., Ltd. xi

PITMAN'S

for Technical Books

★

Telephony (2 Vols.)

By J. Atkinson, A.M.I.E.E., Area Engineer, Post Office Engineering Dept. A completely revised edition of Herbert and Procter's great work, recognised as the standard guide to telephony.

Vol. I (GENERAL PRINCIPLES AND MANUAL EXCHANGE SYSTEMS). 694 illustrations. 35/- net.

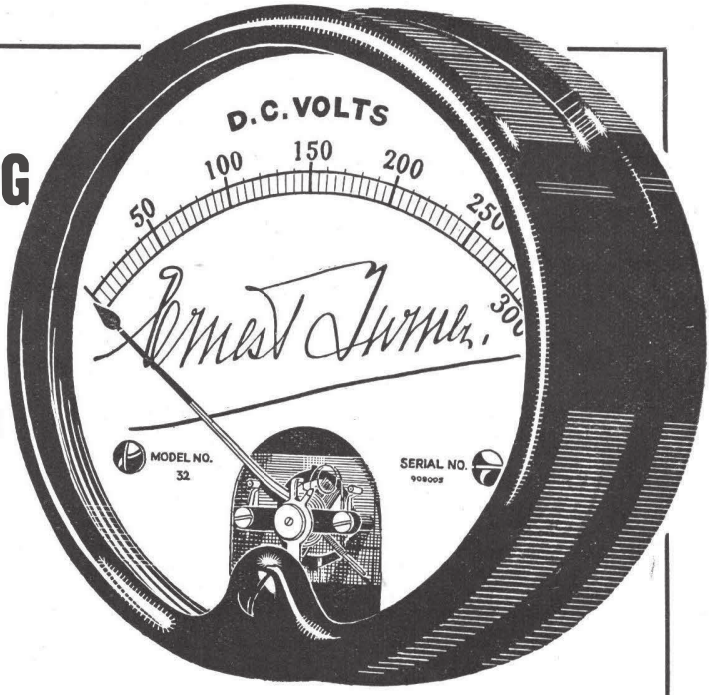
Vol. II (Ready shortly) covers the complete range of automatic telecommunications methods and apparatus. 880 pages. Lavishly illustrated. About 55/- net.

Power System Interconnection

By H. Rissik. The Second Edition of this important work. Thoroughly up-to-date, it is invaluable to the practising electrical engineer and is a reliable textbook for the advanced student. 25/- net.

PITMAN, *Parker Street, Kingsway, London, W.C.2*

ELECTRICAL MEASURING INSTRUMENTS OF THE HIGHER GRADES

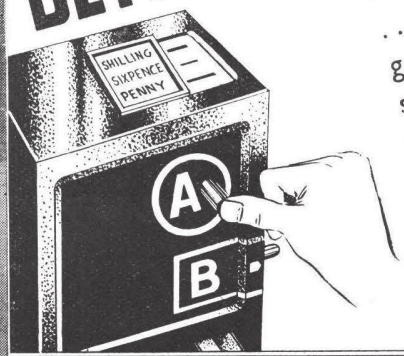


ERNEST TURNER ELECTRICAL INSTRUMENTS LTD.

CHILTERN WORKS, TOTTERIDGE AVENUE, HIGH WYCOMBE, BUCKS.

Telephone : High Wycombe 1301/2 *Telegrams : Gorgeous, High Wycombe*

BEYOND THE BUTTON....



.... Hackbridge underground dry-core air-space lead covered and armoured cable.

Contractors to G.P.O., British Railways, British and Colonial Government Departments.

HACKBRIDGE *Cable Company Limited*

KELVIN WORKS, HACKBRIDGE, SURREY

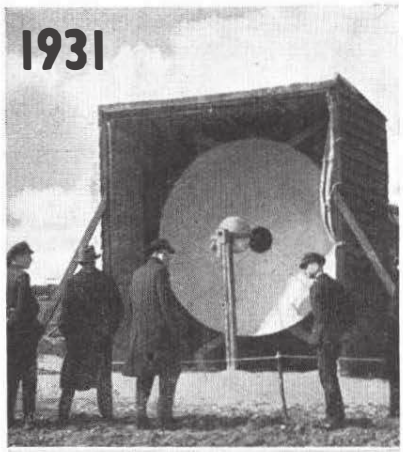
In Association with **Bryce Electric Construction Company Ltd.**

Branches at :

Birmingham, Bristol, Cardiff, Manchester, Newcastle, Sheffield

THREE MILESTONES

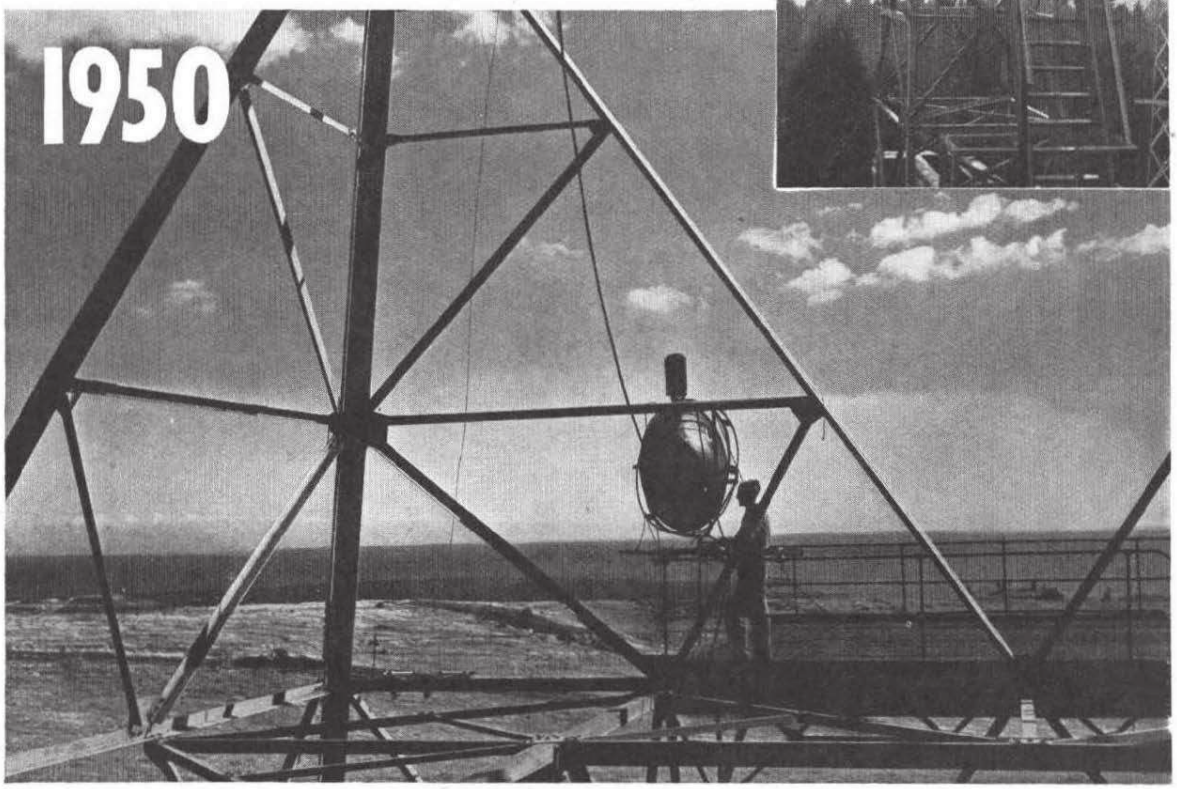
In Transmission History



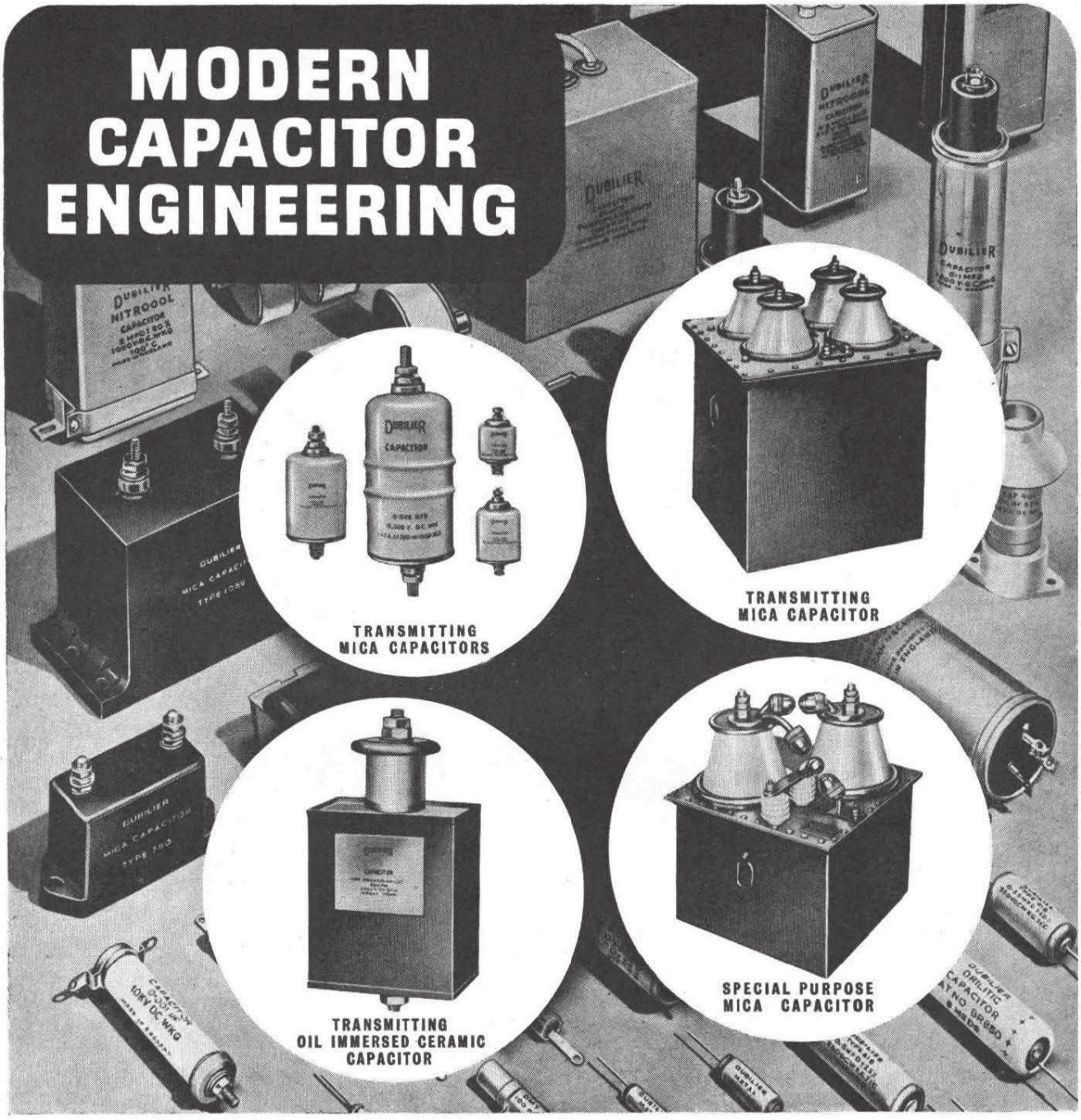
INTO HUNDREDS of thousands of homes in England recently came the modern magic of television pictures transmitted by the B.B.C. from Calais. The television link which spanned the channel was made possible by a quarter of a century's research by STANDARD in the field of Micro-wave technique.

In 1931 STANDARD demonstrated the first Micro-wave radio-telephone circuit between Dover and Calais ; in 1934, a similar system was used to establish the first commercial Micro-wave telegraph link between England and France ; now, for the first time in history, a television transmission has come to England from across the sea, and again a STANDARD Micro-wave link was used to bridge the Channel.

These three milestones in the Company's research programme are indicative of STANDARD'S function—to improve and continue to improve telecommunication on land, at sea, and in the air.



Standard Telephones and Cables Limited Telecommunication Engineers
Connaught House, Aldwych, London, W.C.2



DUBILIER
CAPACITORS

Dubilier provide the most comprehensive range of Capacitors available today for Radio Transmitting and Receiving, in addition to Capacitors for Electronic and Industrial engineering.

Dubilier Capacitors are designed and manufactured to a high standard of specification, suitability of purpose and meticulous capacitor engineering, and they satisfy the exacting demands of the British Postal Authorities whom we are proud to number amongst our customers. Full details and technical service upon request.

DUBILIER CONDENSER CO. (1925) LTD., DUCON WORKS, VICTORIA ROAD, N. ACTON, LONDON, W.3.

'Phone: Acorn 2241 (5 lines). Cables: Hivoltcon, London. Marconi International Code. 'Grams: Hivoltcon, Wesphone, London.

D 49

FERRANTI

7-Range CLIP-ON AMMETER

RANGES

0 – 10 Amps.
0 – 25 "
0 – 50 "
0 – 100 "
0 – 250 "
0 – 500 "
0 –1000 "

FERRANTI

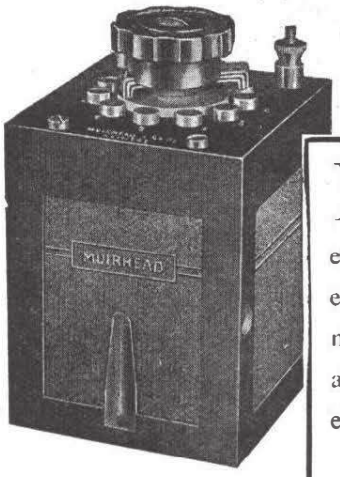
- Thumb-operated switch
- Fully insulated
- Accuracy within 3% of full scale
- Can be applied to bare or insulated conductors up to 2¼ins. diameter
- Weight,.. 3lbs.

Delivery from Stock.

FI 69

FERRANTI LTD., HOLLINWOOD, LANCS.

London Office : Kern House, Kingsway, W.C.2



UNIVERSAL UNITS

RESISTANCE · CAPACITANCE · INDUCTANCE

IN education and in industry, these units find a host of applications There is a physical reality about them which appeals to the elementary student and which is necessarily missing from the more expensive boxes where switches are hidden mysteries and connexions must be taken on trust. This unit form of construction is economical and very convenient, and the moulded containers are sensibly engineered, so that fixing to a panel or to each other is quite simple.

The price for a decade resistance unit is £3 . 8 . 3 and delivery of most types is from stock.

WRITE FOR DESCRIPTIVE LITERATURE

MUIRHEAD & CO., LTD.
PRECISION ELECTRICAL INSTRUMENT MAKERS
BECKENHAM·KENT·ENGLAND
Phone : BECkenham 0041 Telegrams & Cables : MUIRHEADS ELMERS-END

PRECISION MUIRHEAD ELECTRICAL INSTRUMENTS

228

PRODUCTS OF THE COMPANY INCLUDE: DIRECTOR AND NON-DIRECTOR AUTOMATIC TELEPHONE EXCHANGE EQUIPMENT, AUTOMATIC TRUNK EXCHANGES, RURAL AUTOMATIC EXCHANGES, PRIVATE AUTOMATIC EXCHANGES, PRIVATE AUTOMATIC BRANCH EXCHANGES, SINGLE AND MULTI-CHANNEL (CARRIER) TRANSMISSION EQUIPMENT; INTERCOM KEY-CONTROLLED TELEPHONE EQUIPMENT, CENTRALISED SUPERVISORY REMOTE INDICATION AND CONTROL EQUIPMENT; "RYTHMATIC" RIPPLE CONTROL EQUIPMENT; "ELECTRO-MATIC" VEHICLE-ACTUATED TRAFFIC SIGNALS; MINE TELEPHONES AND COLLIERY SIGNALLING EQUIPMENT.

Accurate adjustment of the mechanical parts of the selector guarantees many years of trouble free operation. A delicate touch combined with manipulative skill is required by the adjuster, who is here shown measuring the tension of the rotary interrupter springs.

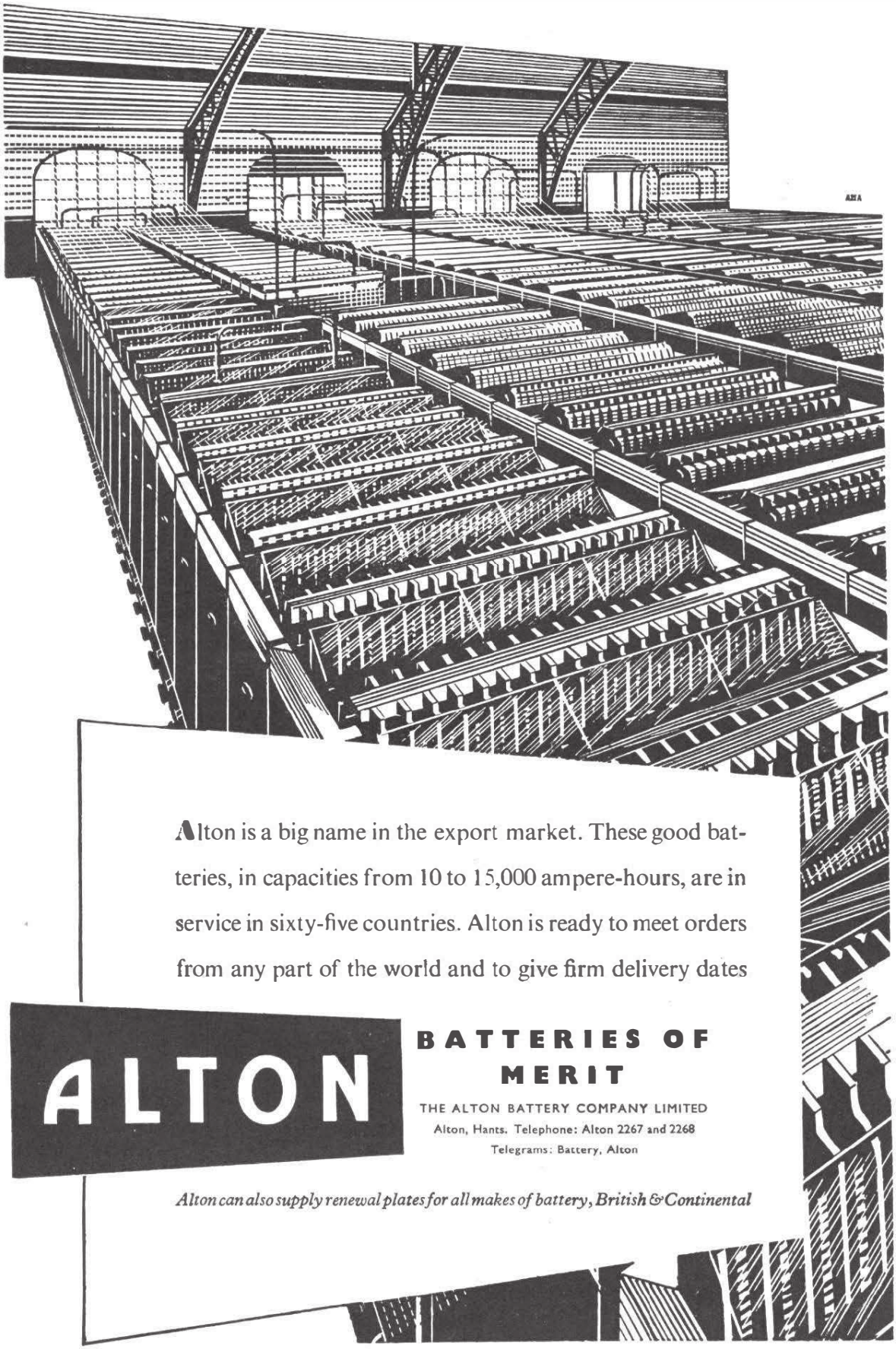
From First Principles to Finished Product

In 1889 Almon B. Strowger made the first mechanism for the automatic selection of a telephone subscriber's line. The principle of selection he adopted was so logical, straight-forward and sound that it has remained unchanged through the intervening years to the present day as the basis upon which more than two-thirds of the world's automatic telephones operate. The type 32A (B.P.O. type 2,000) selector is the basic component of Strowger automatic telephone equipment as manufactured by Automatic Telephone & Electric Co. Ltd. Every week some two thousand of these selectors leave Strowger Works assembly lines and are despatched for service in all parts of the world.

AUTOMATIC TELEPHONE & ELECTRIC CO. LTD.

Export Department: Strowger House, Arundel Street, London, W.C.2. Telephone: TEMple Bar 9262.

Cablegrams: Strowgerex, London. Strowger Works, Liverpool, England



Alton is a big name in the export market. These good batteries, in capacities from 10 to 15,000 ampere-hours, are in service in sixty-five countries. Alton is ready to meet orders from any part of the world and to give firm delivery dates

ALTON

BATTERIES OF MERIT

THE ALTON BATTERY COMPANY LIMITED
Alton, Hants. Telephone: Alton 2267 and 2268
Telegrams: Battery, Alton

Alton can also supply renewal plates for all makes of battery, British & Continental

VALUABLE FREE BOOK

Tells You How to Pass Your C. & G. or Promotion Exam. at *First* Attempt!

All Post Office Engineering personnel who are anxious to obtain early promotion should at once send for a copy of our handbook "**ENGINEERING OPPORTUNITIES.**" which, among other intensely interesting matter, describes our unique methods of preparation for **TECHNICAL APPOINTMENTS IN THE POST OFFICE** (Assistant Engineer—New Style and Assistant Traffic Superintendent), **CITY AND GUILDS EXAMINATIONS** in Principles of Telecommunications (1-5), Radio (1-4), Telephone Exchange Systems (1-3), Telegraphy (1 and 2), Line Transmission (1 and 2), Lines Plant Practice (1 and 2), Mathematics for Telecommunications (1-5), Electrical Engineering Practice (Prelim., Inter. and Final), and outlines a wide range of non-examination courses in all branches of Electrical, Mechanical, Civil, Automobile, Aeronautical and Radio Engineering.

Assistant Engineer and Assistant Traffic Superintendent. Open competitions now resumed. Age extensions for established Civil Servants. Ask us for full details

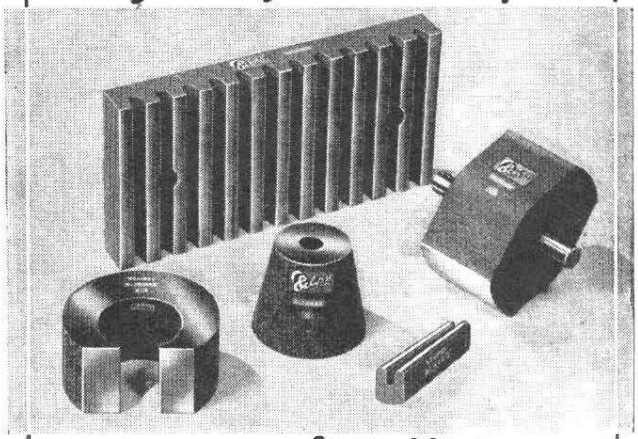
We definitely guarantee "NO PASS—NO FEE"

If you intend to make the most of to-day's opportunities, you cannot afford to miss reading "**ENGINEERING OPPORTUNITIES.**" It tells you everything you want to know to secure advancement, and describes many opportunities you may now be missing through lack of information. Send for your copy to-day—**FREE** and without obligation.

BRITISH INSTITUTE OF ENGINEERING TECHNOLOGY
369 SHAKESPEARE HOUSE, 17-19 STRATFORD PLACE, LONDON, W.1

BIET

Designed by ECLIPSE experts



.... for efficiency

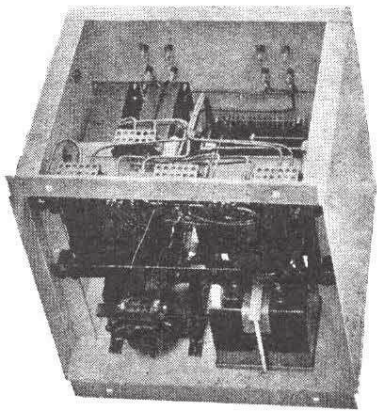
Optimum magnetic performance. No waste material. Lowest cost. Let the "Eclipse" Technical Development Section guide your Permanent Magnet applications—no cost—no obligation.

Eclipse PERMANENT MAGNETS

Made by
JAMES NEILL & COMPANY (SHEFFIELD) LIMITED
COMPOSITE WORKS, SHEFFIELD 11
Designers and Manufacturers of the
ECLIPSE PERMANENT MAGNET CHUCK

CONSTANT POTENTIAL D.C.

from a range of rectifiers designed to give outputs of up to 1200 watts. There are two main types: the "Noregg," which gives an unsmoothed output and is suitable for resistive or inductive loads, the output voltage ripple being approximately 34% at full load, and the "Westat," which includes smoothing and may be used either with a floating battery or direct to a resistive or inductive load.



A 250-watt WESTAT with cover removed.

For details of these

WESTINGHOUSE WESTALITE METAL RECTIFIERS

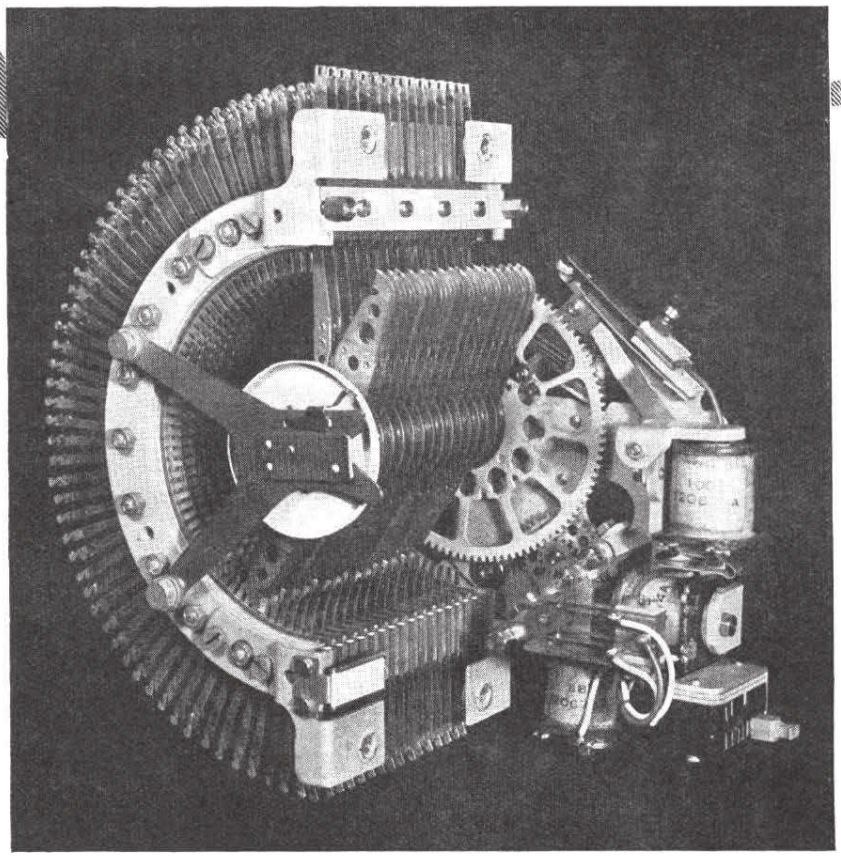
write for Data Sheet No. 62 to Dept. P.O.10

WESTINGHOUSE BRAKE & SIGNAL CO. LTD., 82, York Way, King's Cross, London, N.1

SIEMENS

High-Speed

MOTOR UNISELECTOR



For their Trunk Mechanization Scheme the British Post Office has adopted the High-Speed Motor Uniselector illustrated above.

This Automatic switch has a searching speed of 200 outlets per second. This high speed together with its thorough reliability in operation render it the ideal switch for automatic trunk working.

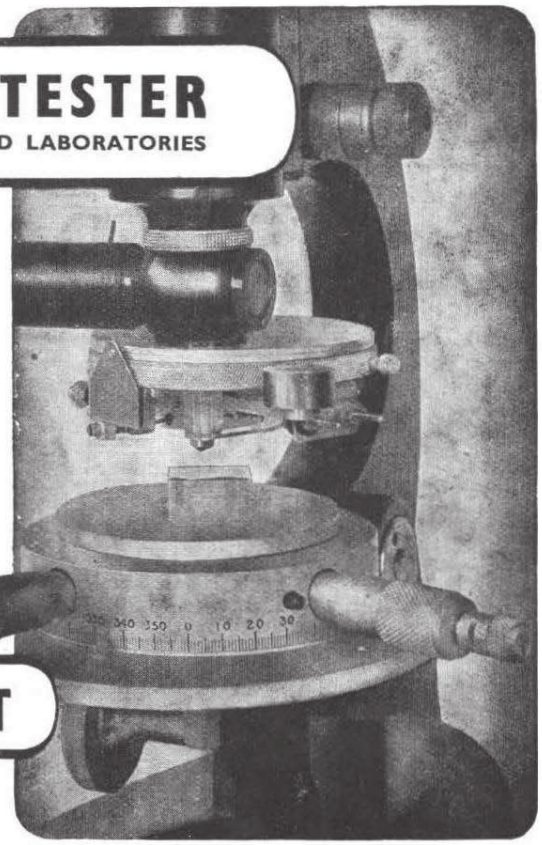
The original type of Motor Uniselector has been in use for Line Finders at North Exchange, London, since June 1935

SIEMENS BROTHERS & CO., LIMITED

WOOLWICH • LONDON • S.E.18.

MICRO-HARDNESS TESTER

DEVELOPED BY THE GUEST, KEEN, NETTLEFOLD LABORATORIES



This new instrument is suitable for use with a standard metallurgical bench type microscope.

It is designed to give a range of loads from 1 to 100 grams with a high degree of accuracy. The associated mechanical stage is provided with micrometer adjustments which permit very accurate movement of the specimen which is necessary for some Micro-hardness investigations. Some applications of this instrument are the measurements of :—

- ★ Hardness of phases of a micro structure.
- ★ Hardness of plated surfaces.
- ★ Case hardening and nitriding.
- ★ Hardness of thin wires, foils and soft metals.
- ★ Hardness variation in cold worked specimens.

Descriptive folder, operating instructions, prices and specialised technical details from sole manufacturers :

AN H.T.A. PRODUCT

HALL TELEPHONE ACCESSORIES LTD.
Precision Engineers and Instrument Makers
70 DUDDEN HILL LANE, LONDON, N.W.10.
Tel.: Willesden 5141 (8 lines) 'Grams: Halltelacc, Harles, London.

SULLIVAN GRIFFITHS

INDUCTANCE STANDARDS

THE ONLY STANDARDS IN USE TO-DAY WHICH ARE UNAPPROACHED THROUGHOUT THE WORLD FOR STABILITY, FREEDOM FROM TEMPERATURE COEFFICIENT AND PERMANENCE OF ALL CHARACTERISTICS.

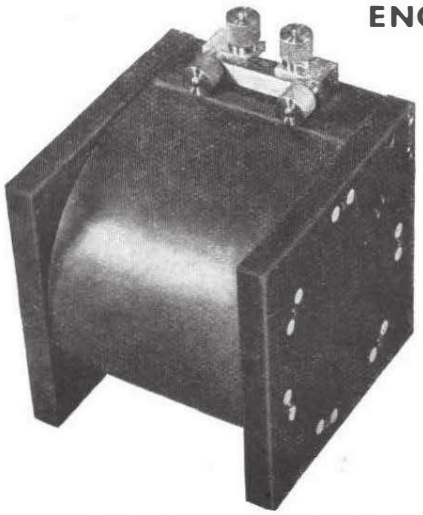
1μH to 1H——— FOR ALL FREQUENCIES
HIGH PERMANENCE——— $< 5 \times 10^{-5}$.
ZERO TEMPERATURE COEFFICIENT———
$< 5 \times 10^{-6}$ PER °C.
ACCURATELY CERTIFIED——— 1×10^{-4}.
ADJUSTED CLOSELY TO NOMINAL VALUE
2×10^{-3}.
LOW SELF CAPACITANCE.———
EXTREMELY LOW LOSSES.———
EXCELLENT FREQUENCY. CHARACTERISTICS OF BOTH L AND R.———

H. W. SULLIVAN
LIMITED
LONDON, S.E.15

Telephone : New Cross 3225 (P.B.X.)———

Electrical Standards for Research and Industry

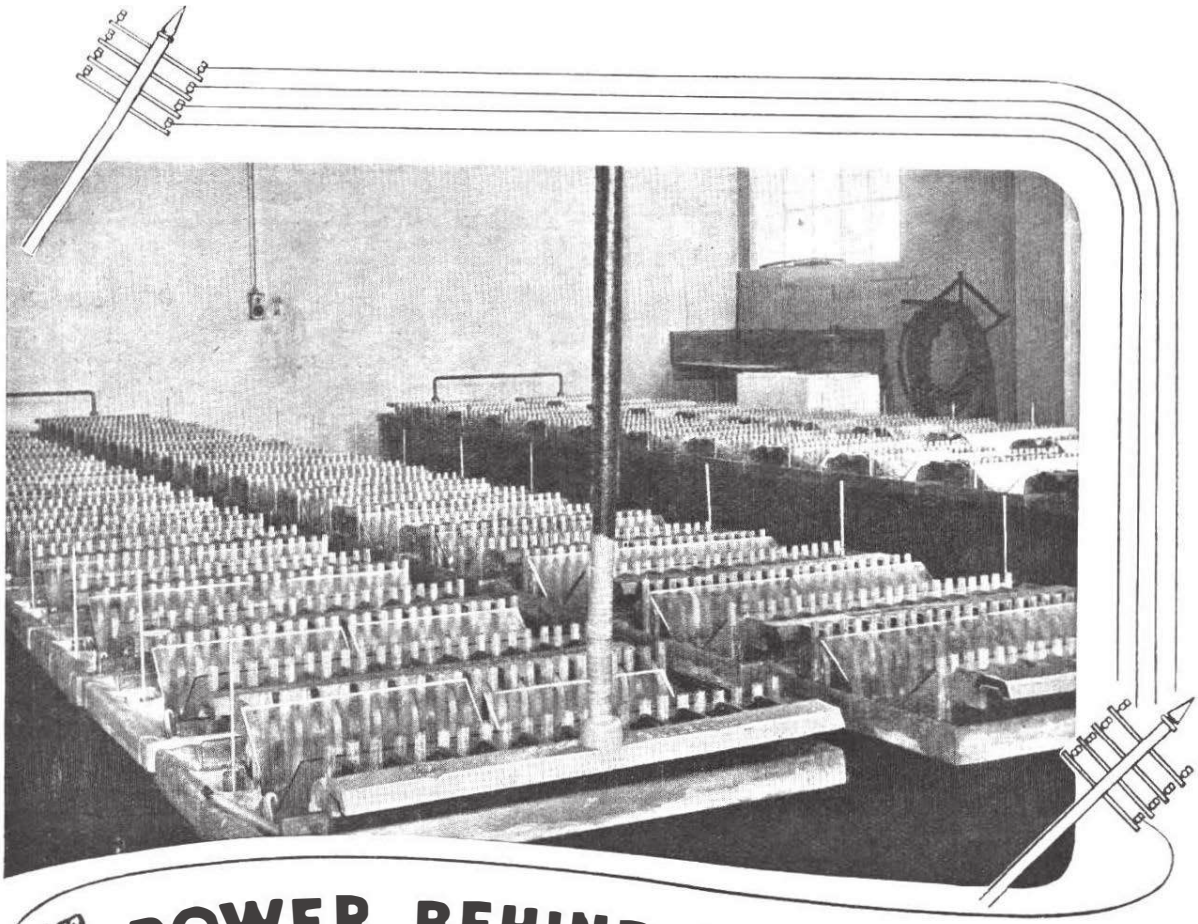
Testing and Measuring Apparatus FOR COMMUNICATION ENGINEERING



THESE STANDARDS ARE ALSO AVAILABLE IN VARIABLE AND DECADE FORM AND ALSO ARRANGED FOR MUTUAL INDUCTANCE

The illustration shows the new terminal arrangement which is now fitted to all coils to facilitate the reproduction of standardisation condition

ESSENTIAL FOR ACCURATE WAVEMETERS AND BEAT-TONE-OSCILLATORS.
INDISPENSABLE FOR USE AS REFERENCE STANDARDS IN COMMUNICATION ENGINEERING.



POWER BEHIND THE LINES

TUNGSTONE PLANTÉ CELLS are being supplied to the British Post Office and Post and Telegraph Departments in many countries overseas. They conform fully to G.P.O. and British Standard specifications.

OPEN TYPE CELLS

Similar to the illustration above, these are available in glass and/or lead lined wooden boxes in capacities from 100 a.h. to 500 a.h.

ENCLOSED TYPE CELLS

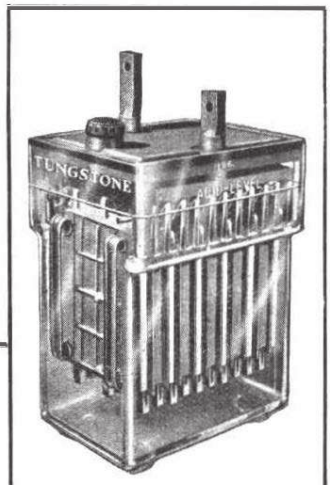
As illustrated on the right, these are in moulded glass boxes with sealed-in lids. Capacity range from 10 a.h. to 200 a.h.

REPLATALS

We are in a position to supply plates for the replating of any existing Planté Battery.

HIGH VOLTAGE TELEPHONE BATTERIES

Portable Type. Standard layout for 50 volts, in waxed hard wood crates, exactly to the requirements of the G.P.O.



Overseas customers are invited to cable or write their enquiries for batteries or parts. Visitors to London are welcome at our offices.

TUNGSTONE *Batteries*

For further particulars write : **TUNGSTONE PRODUCTS LIMITED**
10 SALISBURY SQUARE · LONDON · E.C.4 · ENGLAND. Cables: "Dilutum" London.

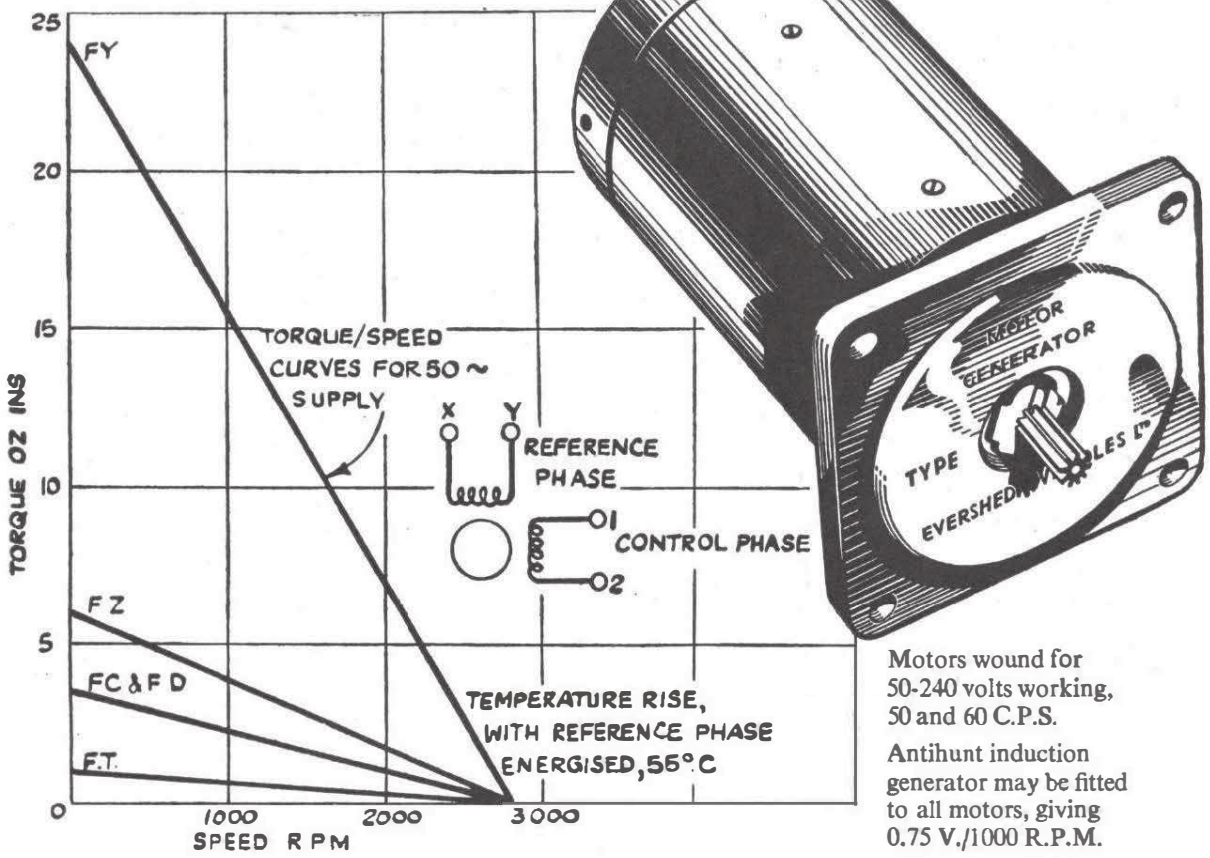
T.B.12

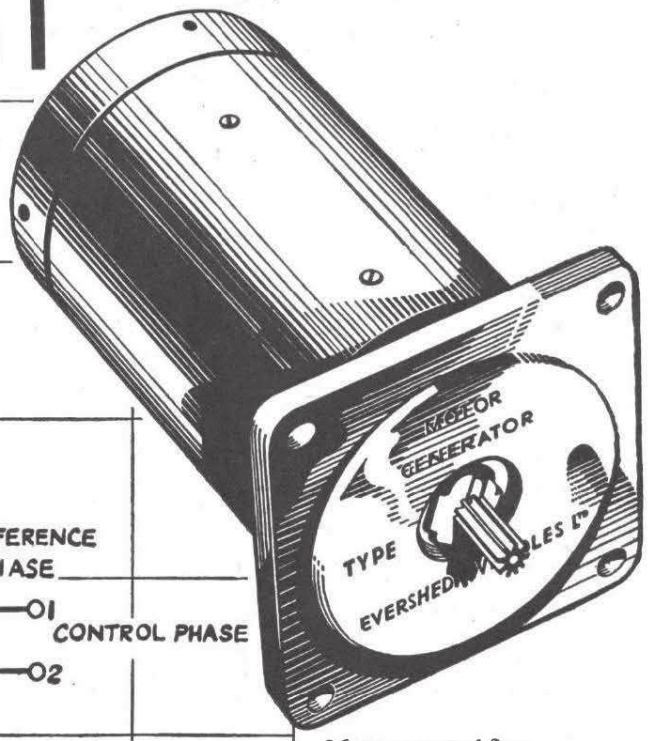
DATA SHEET No. 2

EVERSHED

SPECIAL DUTY F.H.P. MOTORS

TYPICAL A.C. SERVO MOTORS FOR ELECTRONIC CONTROL





FRAME SIZE	MOMENT OF INERTIA OZ. INS.²	REFERENCE PHASE WATTS.	CONTROL PHASE WATTS.	OUTPUT WATTS.
F.T.	.10	—	—	—
F.C.	.18	8.6	11	2.5
F.D.	.2	8.6	11	2.5
F.Z.	.27	12.0	12	4.5
F.Y.	.6	35.0	35	17.0

Motors wound for 50-240 volts working, 50 and 60 C.P.S.

Antihunt induction generator may be fitted to all motors, giving 0.75 V./1000 R.P.M.

All motors rated for a temperature rise with reference phase energised of 55°C.

Send for the Evershed Small Motors' Data Book. X 22.

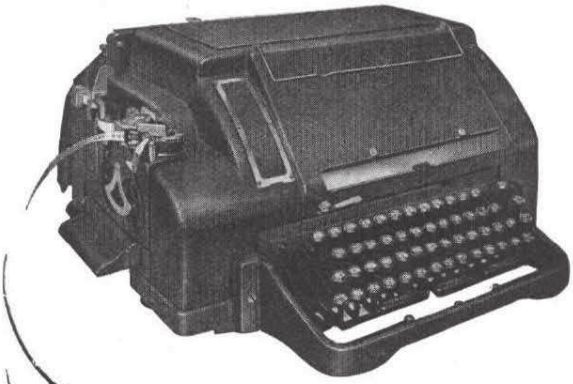
EVERSHED AND VIGNOLES LIMITED

ACTON LANE WORKS · CHISWICK · LONDON · W4

Telephone: Chiswick 3670 *Telegrams: Megger, Chisk, London* *Cables: Megger, London*

Creed
TELEPRINTERS

Built by specialists in machine telegraphy~



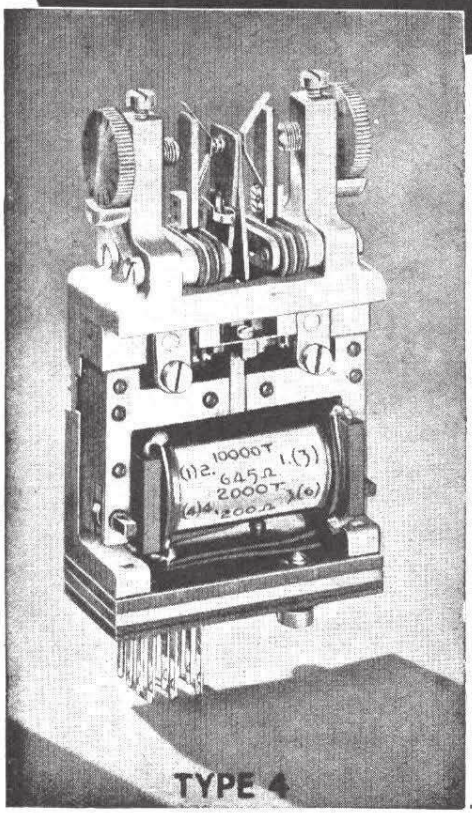
N° 47 TAPE MODEL

Write for Bulletin N° 21

Creed & Company Limited

TELEGRAPH HOUSE
CROYDON, ENGLAND

CARPENTER Polarized RELAY
TYPE 4



This is a medium speed, sensitive relay with long contact travel designed primarily as a telephone impulsing relay (D.C. dialling up to 100 miles and V.F. dialling on trunk circuits). It has also been successfully adopted for use in Telex systems.

Its sensitivity is such that when the gap is adjusted to .004 in. the relay will just operate at 50 cycles with 4 ampere-turns (corresponding to approximately 1 mVA) or on 2½ D.C. ampere-turns at low speeds. In service, however, the relay is normally operated at currents substantially larger than the minimum operating current.

Contact chatter is absent if the contact gap does not exceed .004 in. The contact gap is adjustable by means of fine pitch screws with knurled heads marked with .001 in. divisions.

Contacts on the armature tongue are insulated from it and thereby from the frame.

Terminals for soldered connections are fitted as standard.

The relay is supplied with a magnetic screening cover with transparent removable top to facilitate contact adjustment.

Dimensionally the relay is interchangeable with the type "3000" relay and can be supplied to fit directly to the drilling normally provided for the "3000" relay.

Dimensions of the Type 4 Carpenter Relay are :—(With cover. Excluding wiring tags) $3\frac{9}{16}$ ins. high × $2\frac{3}{16}$ ins. wide × 1 in. deep. Weight: 13 ozs.

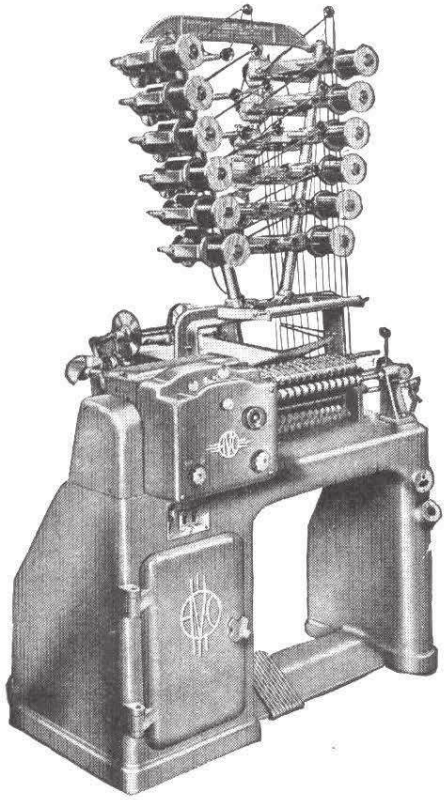
Complete details available on request. *Manufactured by the Sole Licensees :—*

TELEPHONE MANUFACTURING CO. LTD.

Contractors to the British Commonwealth and Foreign Governments

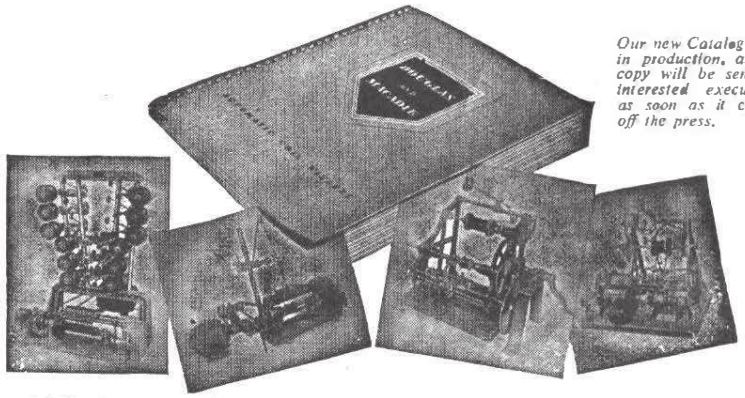
HOLLINGSWORTH WORKS DULWICH LONDON, S.E.21

Telephone : GIPsy Hill 2211 (10 lines)



DOUGLAS AND MACADIE
Automatic
COIL WINDERS

The large illustration depicts the improved "Douglas" Fully Automatic Multi-Winder, specially developed for the high-speed production of large quantities of coils with or without paper interleaving. It will produce round, square or rectangular coils up to 6 in. each in length and up to 4½ in. diameter. As many as 12 smaller coils can be wound simultaneously within the total available winding length of 12 in. at headstock speeds of between 600 and 2,000 r.p.m.



Our new Catalogue is in production, and a copy will be sent to interested executives as soon as it comes off the press.

Sole Proprietors and Manufacturers :

The AUTOMATIC COIL WINDER & ELECTRICAL EQUIPMENT CO. LTD.

WINDER HOUSE · DOUGLAS STREET · LONDON · S.W.1 *Telephone : VICTORIA 3404/9*

Television...moves

A new repeater . . .

. . . . to the design of the British Post Office is in production at the G.E.C. Telephone, Radio and Television Works, Coventry, for application to coaxial cables between London and Holme Moss, near Manchester.

To be installed at intervals of approximately six miles, the repeater will amplify vision signals in both directions of transmission. It will bring the B.B.C. television programme to the densely-populated area within a wide radius of Manchester, and will carry south television programmes from Manchester.

Thus the G.E.C., who brought television from London to Birmingham by wideband U.H.F. radio link, now figure in the further extension by the alternative transmission by line.

G.E.C.

The Largest British Electrical Manufacturing Organisation in the World

THE GENERAL ELECTRIC COMPANY LTD. OF ENGLAND

TELEPHONE, RADIO AND TELEVISION WORKS · COVENTRY · ENGLAND

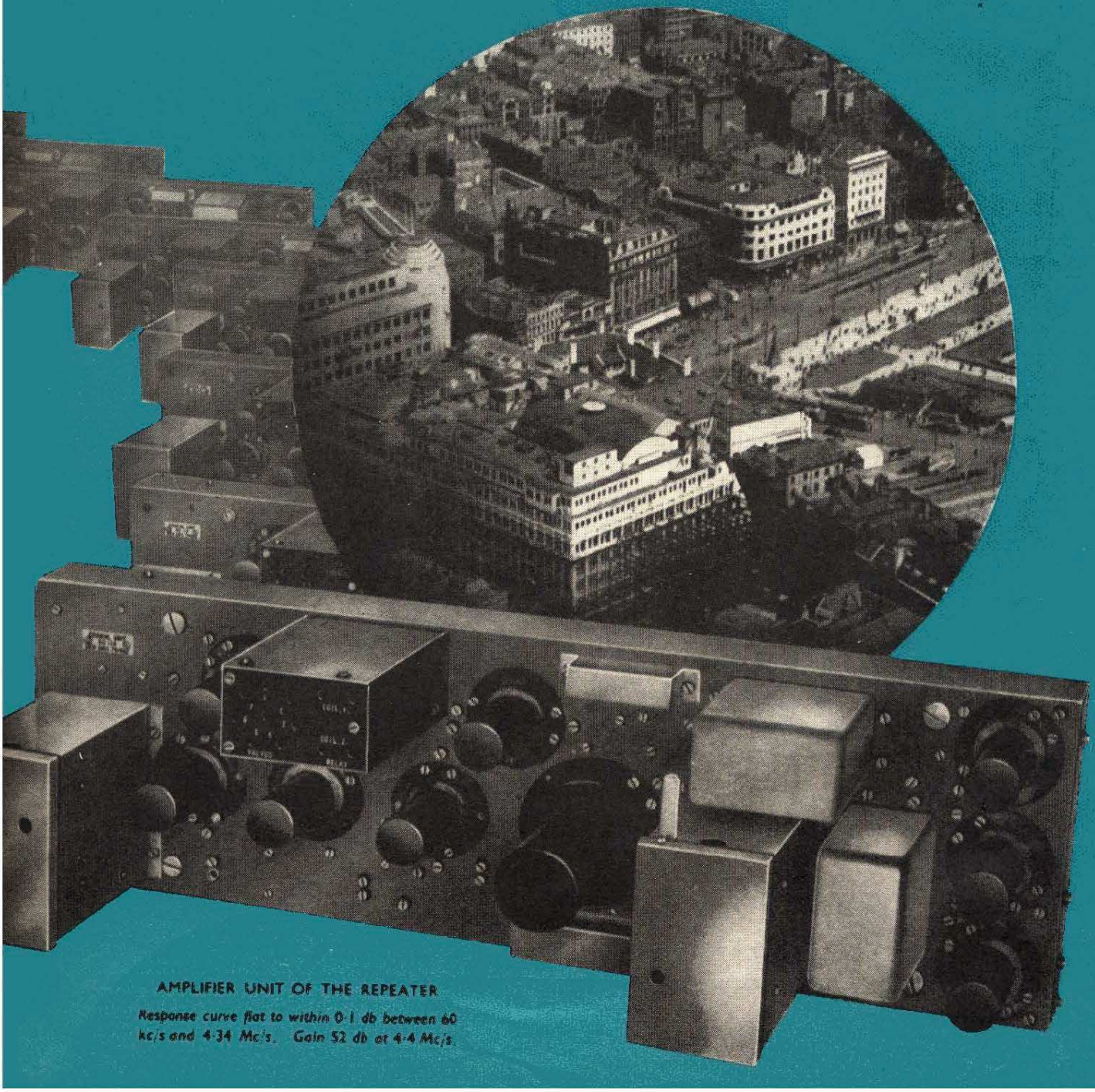
Telephone : Coventry 4111 (10 lines) *Telegrams and Cables : "Springjack, Coventry"*

HEAD OFFICE · MAGNET HOUSE · KINGSWAY · LONDON · W.C.2

Temple Bar 8000 (90 lines) *"Electricity, Westcent, London"* *Cables : "Polyphase London"*

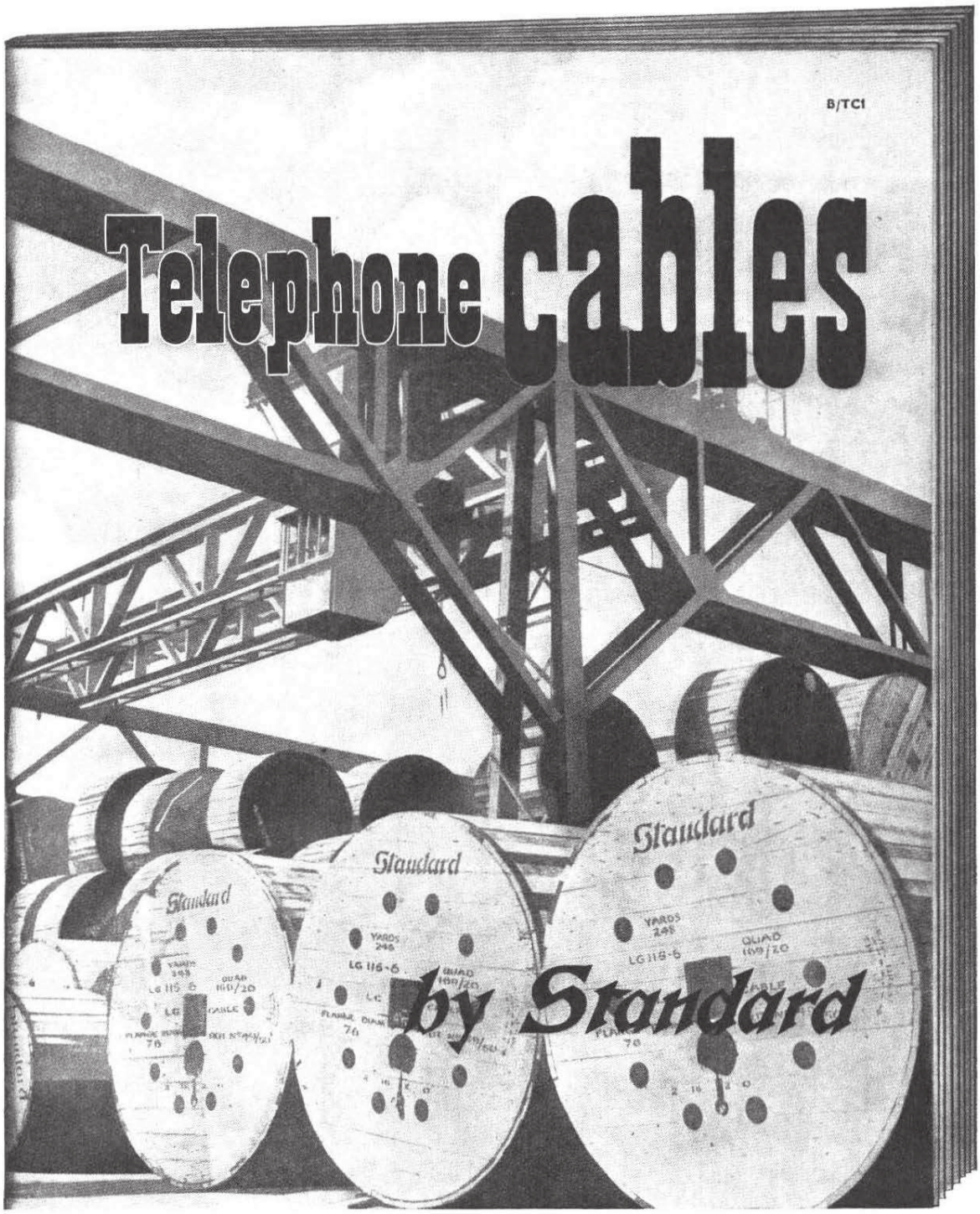
to Manchester...

...by repeatered line...



AMPLIFIER UNIT OF THE REPEATER

Response curve flat to within 0·1 db between 60 kc/s and 4·34 Mc/s. Gain 52 db at 4·4 Mc/s



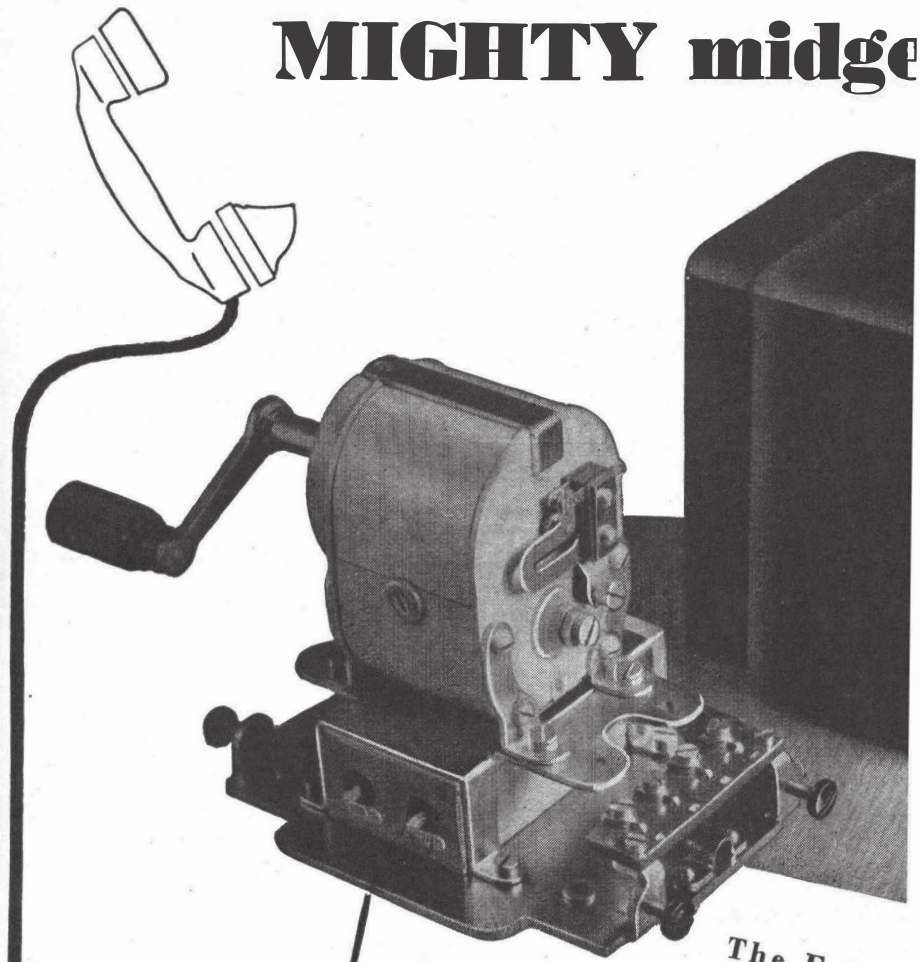
THIS catalogue, No. B/TC 1, contains the latest information on a wide range of telecommunication cables manufactured by "STANDARD."

Standard Telephones and Cables Limited

(Registered Office : Connaught House, Aldwych. London, W.C.2)

TELEPHONE LINE DIVISION. NORTH WOOLWICH, LONDON, E.16

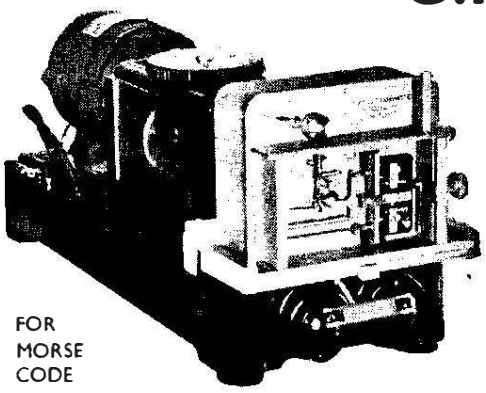
MIGHTY midge



The Ericss
GENERATO
a robust yet ele
Ericsson practice. Has an output equiv
4-Bar unit but is less than half its si
Certified safe for use in mines, and ca
unmounted or without the moulded
Our heavy duty ALNICO
but uses the

UNIVERSALLY ADOPTED

G.N.T.Co. TRANSMITTER MODEL 112



FOR MORSE CODE

13-250 words per minute without gear changes or readjustments.

Absolutely constant speed at all settings notwithstanding large voltage variations.

Noted for its easy maintenance.

Supplied with A.C. or D.C. motors as required.

THE GREAT NORTHERN TELEGRAPH CO. LTD.

OF DENMARK

KONGENS NYTORV 28
COPENHAGEN K. - DENMARK

AND

5, ST. HELEN'S PLACE,
LONDON, E.C.3

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

PRINTED PAPERS

The following papers contributed to the proceedings of the Institution have been printed by the authority of the Council and may be obtained, if still in print, from

"THE LIBRARIAN, THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS, G.P.O. (ALDER HOUSE), LONDON, E.C.1."

The prices do *not* include postage. Members, Associate Members, and Associates have the privilege of purchasing copies at two-thirds the stated price.

†No. 184.	"THE FUNDAMENTALS OF DIRECT CURRENT IMPULSING IN MULTI-EXCHANGE AREAS."—S. WELCH, M.Sc.(Eng.), A.M.I.E.E. 1944	1s. 6d.
†No. 185.	"THE OPERATION OF VALVE OSCILLATORS AND THEIR SYNCHRONISATION."—A. C. LYNCH, M.A., J. R. TILLMAN, Ph.D., and D. G. TUCKER, Ph.D., A.M.I.E.E. 1944	1s.
†No. 187.	"CABLING PROBLEMS IN SUBWAYS AND TUNNELS."—T. G. TURLEY, A.M.I.E.E. 1945	1s.
No. 188.	"POWER SUPPLIES FOR TELEGRAPHS."—G. N. DAVISON B.Sc.(Eng.), D.I.C., A.M.I.E.E. 1945	1s. 6d.
†No. 189.	"DEVELOPMENT OF TELEGRAPH SWITCHING IN GREAT BRITAIN."—J. A. S. MARTIN, A.M.I.E.E., and J. W. FREEBODY, Whit. Schol., B.Sc.(Eng.), D.I.C., A.M.I.E.E. 1944	1s. 6d.
†No. 190.	"WIDEBAND TRANSMISSION OVER COAXIAL CABLES."—R. A. BROCKBANK, Ph.D., B.Sc., A.M.I.E.E., and C. F. FLOYD, M.A., A.M.I.E.E. 1946	1s. 6d.
No. 191.	"PIEZO-ELECTRIC QUARTZ AND ITS USE IN TELECOMMUNICATIONS."—C. F. BOOTH, M.I.E.E., and J. L. CREIGHTON, A.M.I.E.E.	1s. 6d.
†No. 192.	"THE LOCATION OF FAULTS IN LINES AND CABLES."—CAPT. A. C. TIMMIS, B.Sc., M.I.E.E. 1948.	1s. 6d.
†No. 193.	"IMPROVEMENTS IN TELEPHONE SIGNALLING."—S. WELCH, M.Sc.(Eng.) A.M.I.E.E., and C. H. J. FLEETWOOD, A.M.I.E.E. 1949.	1s. 6d.
†No. 194.	"MAINTENANCE OF MULTI-CHANNEL CARRIER TELEPHONE SYSTEMS."—F. O. MORRELL, B.Sc. A.M.I.E.E. 1948.	1s. 6d.
†No. 195.	"THE INTRODUCTION OF AUTOMATIC SWITCHING TO THE INLAND TELEPRINTER NETWORK."—H. E. WILCOCKSON, A.M.I.E.E., and C. W. A. MITCHELL, A.M.I.E.E. 1949.	1s. 6d.

† The Council have awarded Institution Medals for these papers.

Denso

Regd. Products

has your Corrosion Problems TAPED

Denso Tape protects mains, services and all metalwork, below or above ground, against the menace of chemi l and electrolytical corrosion. Ideal for water- and gas-proofing and an aid to frost-proofing. Emergency repairs to gas mains and services. Water-proofing temporary cable openings.
Specifications and Price Lists of "Denso" Anti-corrosive and Sealing Products without obligation from :—

WINN & COALES LTD.

33/35a CHAPEL ROAD, LONDON, S.E.27

Telephone : Gypsy Hill 3089. *Telegrams : DENSELTE, WESTNOR, LONDON.*

SOUND INSTRUCTION by Postal Method

The I.C.S., largest school in the world devoted to spare-time training by the postal method, offers you highly specialised Courses for the following examinations:

P.M.G. Certificates for Wireless Operators.
C. & G. Illumination Engineering (Inter.)
C. & G. Electrical Engineering Practice, Installation and Telecommunications.
Graduateship of the B.I.R.E.

I.C.S. Examination students are coached till successful.

Other Courses meet the requirements of all who desire to qualify for responsible positions in Electric Power, Illumination, Heating and Traction Systems. Equally successful is our instruction for Telegraph and Radio Engineers, Radio Servicemen, and in Elementary Radar and Electronics, Advanced Short-Wave Radio and Television Technology.

Instruction is by correspondence from textbooks specially prepared by many experts.

WRITE FOR OUR SPECIAL BOOKLET and state the particular subject or Examination in which you are interested.

YOU MAY USE THIS COUPON

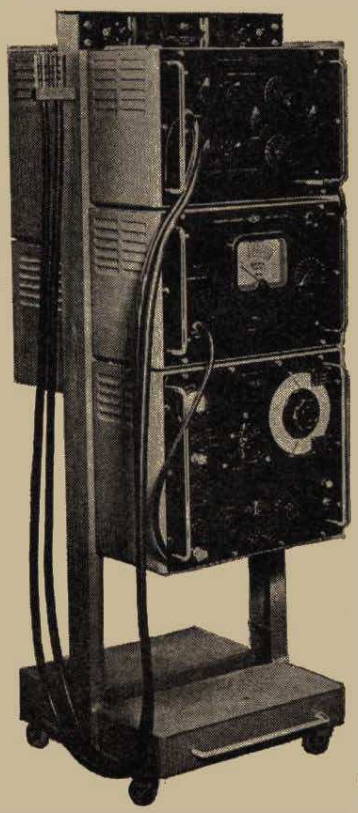
International Correspondence Schools Ltd.
Dept. 108, International Buildings, Kingsway, London, W.C.2

Please send me, free of charge, your special booklet on.....

Name..... *Age*.....
(BLOCK LETTERS, PLEASE)

Address.....

ICS



AIRMEC

PHASE MEASURING EQUIPMENT

Type RX 103

This equipment, which is based upon a Post Office design, is primarily intended for the measurement of the phase-shift and gain of the $\mu\beta$ characteristics of feedback repeaters, over the frequency range of 50 kc/s to 20 Mc/s. It is also suitable for similar measurements on amplifiers, filters, equalisers and other four-terminal networks.

AIRMEC LABORATORIES LTD

HIGH WYCOMBE · BUCKINGHAMSHIRE · ENGLAND

TEL. HIGH WYCOMBE 2060 *CABLES: AIRMEC HIGH WYCOMBE*

A.L. (c) 4

TELEPHONE CABLES

OUR BROCHURE No. 9E (1949), GIVING INFORMATION AND SPECIFICATIONS FOR A WIDE RANGE OF TELECOMMUNICATION CABLES MANUFACTURED BY US, IS AVAILABLE UPON REQUEST.

TELEPHONE: SOUTHAMPTON 2141 (5 lines)

PIRELLI-GENERAL

CABLE WORKS, Ltd., SOUTHAMPTON.

TELEGRAMS "PIGEKAYBEL SOUTHAMPTON

MINIATURE VITREOUS ENAMELLED RESISTOR

TYPE M.V.I

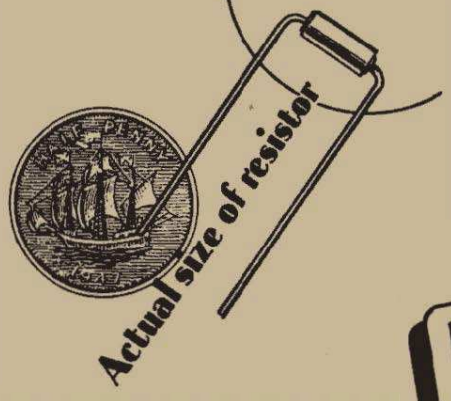
RATING 3 watts for 250°C. rise.

RESISTANCE RANGE - 1-4700 ohms.

Full rated watts over the whole resistance range.

DIMENSIONS - 15/32" × 13/64".

Agents in Switzerland: Arnold Kleiner, Zug



TYPE APPROVED

PAINTON of NORTHAMPTON

KINGSTHORPE, NORTHAMPTON.

Printed by SANDERS PHILLIPS & CO., LTD., The Baynard Press, Chryssell Road, London, S.W.9, and Published by BIRCH & WHITTINGTON (*Prop. Dorling & Co [Epsom], Ltd.*), Epsom, Surrey.

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

VOL. 43 JANUARY 1951 PART 4

CONTENTS

	PAGE
A TRAILER MOTOR DESICCATOR EMPLOYING SILICA GEL—J. J. Moffatt, A.M.I.E.E.	165
NATIONAL TRUNK DIALLING—R. W. Gibson, A.M.I.E.E.	169
INTRODUCTION TO ELECTRONIC AUTOMATIC TELEPHONE EXCHANGES: REGISTER-TRANSLATORS—T. H. Flowers, M.B.E., B.Sc., M.I.E.E.	177
A DRAWING OFFICE AID IN ISOMETRIC PROJECTION—R. H. Chapman, B.Sc., A.M.I.E.E., and E. C. Shipley	184
A SURVEY OF MODERN RADIO VALVES—Part 6 (b).—Valves for Use at Frequencies Above 3,000 Mc/s—W. J. Bray, M.Sc.(Eng.), A.C.G.I., D.I.C.	187
THE USE OF A PISTON ATTENUATOR FOR CABLE TESTING IN THE FREQUENCY RANGE 1-30 Mc/s—E. C. H. Seaman, B.Sc.(Eng.), A.M.I.E.E., D. A. Crow, B.Sc.(Eng.), A.C.G.I., A.M.I.E.E., and C. G. Chadburn	192
A SIMPLE PHASE MEASURING CIRCUIT—R. A. Seymour	198
THE CALCULATION OF PHASE CONSTANT FROM SMALL DIFFERENCES OF OPEN AND CLOSED IMPEDANCE—P. R. Bray, M.Sc.(Eng.), A.M.I.E.E.	200
THE IMPLEMENTATION OF THE NEW RADIO FREQUENCY ALLOCATION TABLE	202
COMMISSION MIXTE INTERNATIONALE (C.M.I.), Paris, 1950	205
OBITUARY—Sir Frank Gill, K.C.M.G., O.B.E., Hon.M.I.E.E.	207
NOTES AND COMMENTS	208
INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS	210
REGIONAL NOTES	212
JUNIOR SECTION NOTES	217
STAFF CHANGES	219
INDEX TO VOL. 43	222
BOOK REVIEWS	168, 176, 191, 197, 218

Price 1/6 net

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

STUDY AT HOME

You Can Have a College Training For a Few Shillings Monthly

IN YOUR SPARE TIME

CITY and GUILDS
(Telecommunication)
EXAMINATIONS

The most progressive and most successful Correspondence College in the world

To every student we send a written Guarantee of Tuition until the examination is actually passed

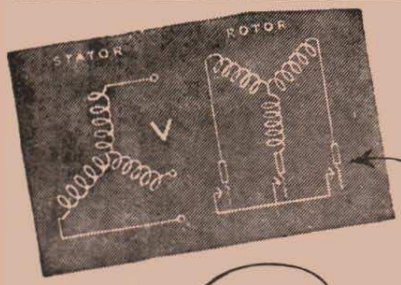
Our tuition is so graded that each stage is reached without difficulty.

Personal attention is given to every student.

FULL PARTICULARS AND ADVICE SUPPLIED FREE.
WE TEACH BY POST IN ALL PARTS OF THE WORLD.

The Bennett College Limited

Dept. 24, THE BENNETT COLLEGE, SHEFFIELD



A.C. Polyphase Wound Rotor - Rotor Rheostat.

FOR EVERY PHASE OF ELECTRICAL WORK

The British Electric Resistance Co. Ltd. can answer the multitude of resistance problems that beset the electrical circuit designer. For twenty years Berco resistances have been giving reliable and steadfast service, and the Berco range is designed to meet every requirement.

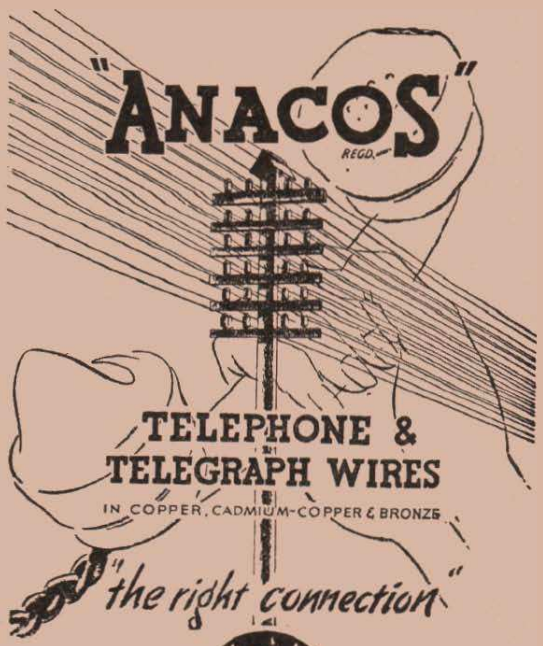
Berco engineers are specialists in resistance design and their knowledge is at your disposal.

BERCO

RESISTANCES

THE BRITISH ELECTRIC RESISTANCE CO. LTD.
Queensway, Ponders End, Middlesex
Telephone: Howard 1492 Telegrams: Vitrohm, Enfield
BR2033-2Q

"ANACOS" REGD.

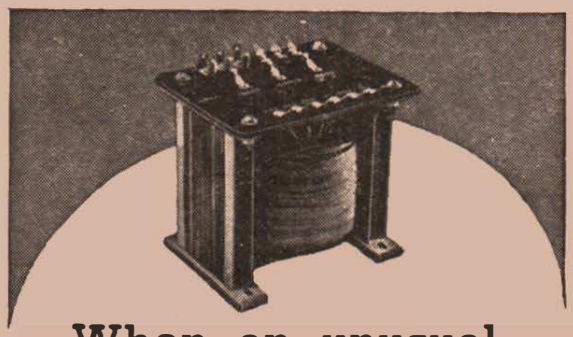


TELEPHONE & TELEGRAPH WIRES
IN COPPER, CADMIUM-COPPER & BRONZE

"the right connection"

FS

FREDERICK SMITH & COMPANY
(Incorporated in The London Electric Wire Company and Smiths, Limited)
ANACONDA WORKS, SALFORD 3, LANCS.
Phone: Blackfriars 8701 (9 lines) Grams: "Anaconda," Manchester



When an unusual Specification is required.

We can give you the benefit of 20 years' experience in transformer construction and design. We manufacture quantities but we do NOT mass produce. Every Instrument is built to suit your most exacting individual specification.

Send your enquiries for the personal attention of our Mr. W. Bryan Savage.

SAVAGE TRANSFORMERS OF DEVIZES LIMITED

SAVAGE TRANSFORMERS LTD. ● NURSTED ROAD, DEVIZES, WILTS.

THE POST OFFICE
ELECTRICAL ENGINEERS' JOURNAL

Vol. 43 January, 1951 Part 4

A Trailer Motor Desiccator employing Silica Gel

J. J. MOFFATT, A.M.I.E.E.

U.D.C. 66.047:621.434:621.315.21

A description is given of a petrol-engine-driven desiccator in which the drying agent, silica gel, can be reactivated periodically by heat supplied from the engine exhaust gases. The complete equipment is trailer-mounted and has proved to be a valuable maintenance aid in effecting rapidly the temporary restoration of cables affected by the ingress of moisture.

Introduction.

WITH the existing multiplicity of circuits provided by air-spaced paper-core cables and coaxial cables, the risk of considerable dislocation of traffic exists through the failure of such cables. Failures may arise from various causes, prominent amongst which is the penetration of water through cracks or punctures in the cable sheath. When such conditions develop, the first intimation that is received may be that the electrical characteristics of the cable have fallen to such a level as to make the circuits unworkable. Permanent restoration of the cable generally necessitates renewal of the faulty length, but there are occasions when very real economies can be effected and much inconvenience saved if the cable can be restored to service by desiccation and the main repair work carried through later when the stress and urgency of breakdown conditions have been removed.

Restoration of the existing, but faulty, cable may often be accomplished by passing dry gas through the cable and removing the offending moisture. While carbon dioxide or dry air are so employed to-day, the former, although conveniently supplied from the familiar gas cylinders, collects in jointing chambers at the discharge points and requires to be dispersed before permanent repairs are completed. The second alternative generally involves the use of calcium chloride for drying the air before it is pumped through the cable, a method which has a number of disadvantages, particularly when viewed under breakdown conditions. The motor-driven desiccator, described below, uses silica gel as the adsorbent material and is considered to possess advantages over the usual methods of desiccation.

General Description.

The petrol-engine-driven desiccator which forms the subject of this article is based upon the principle of using silica gel as the moisture-adsorbent material and employing the waste heat in the engine exhaust gases to reactivate the silica gel when it becomes saturated. The practicability of this principle was established by P.O. Research Report No. 7612. By the use of two beds of silica gel—one drying the air while the other is being reactivated—the operation of the unit may be continued without interruption as long as the engine is supplied with fuel. The system is shown schematically in Fig. 1.

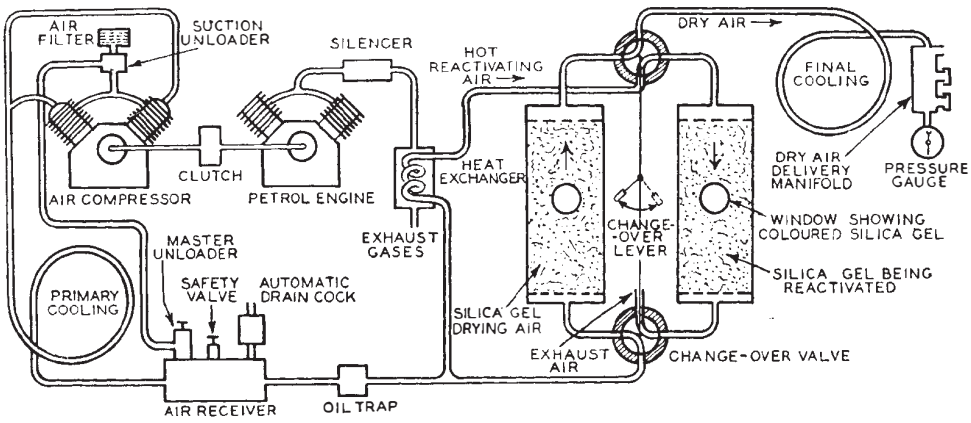


FIG. 1.—SCHEMATIC ARRANGEMENT OF DESICCATOR.

The trailer-mounted apparatus is constructed to meet the Departmental requirements and consists of an air-cooled petrol engine driving an air compressor. The bulk of the compressed air passes through one of the silica-gel beds and thence to the cables, while the remainder is heated by a heat-exchanger and is then fed through the second bed of silica gel to blow-off the water vapour liberated from the silica gel by virtue of the heat in this air. After one bed has been used as the drier for a time, the change-over of action is effected rapidly by a single lever connected to a pair of double-port valves. A number of accessories are also incorporated, e.g. automatic unloader, automatic drain cock, safety valve, etc., enabling the units to be operated with the maximum efficiency by staff that have not been specially trained in the use of the equipment.

Prime Mover.

The prime mover is a standard commercial twin-cylinder, air-cooled petrol engine developing approximately 10 h.p. at 1,000 r.p.m. Although this type of engine is normally governor controlled, a means is provided of reducing the engine speed to a minimum of approximately 800 r.p.m. in order that the power used may be approximately in proportion to the dry air consumed. Reduction in the engine speed below 800 r.p.m. is not practicable, because of the difficulties that arise through ineffective cooling and lubrication. A fan is provided on the engine for cooling purposes.

The output drive is transmitted via a spring-loaded centrifugal clutch to enable the mechanical load from the compressor to be excluded until the engine has been started and has gathered speed. The clutch engages at approximately 200 r.p.m.

Air Compressor.

The air compressor (see Fig. 2) is of the twin-cylinder, air-cooled type and is fan-cooled. The atmospheric air passes through an air filter before being compressed. The compressor employed is the nearest suitable commercial size to give the required output of 10 cu. ft. of air per minute at 30 lb. per sq. in.

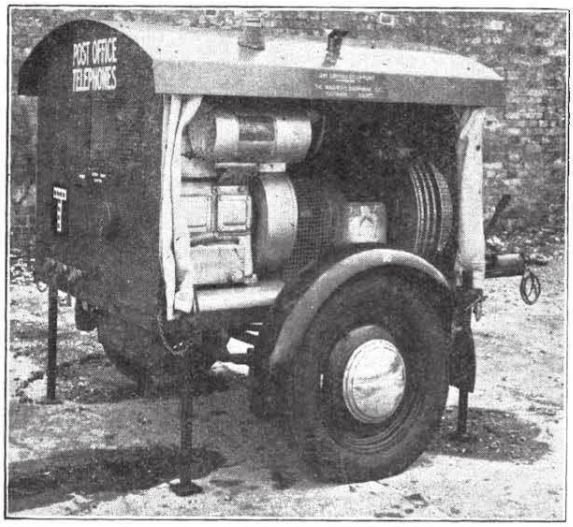


FIG. 2.—ENGINE AND COMPRESSOR SIDE OF THE DESICCATOR.

Air Receiver.

An air receiver of welded construction is employed which conveniently provides a means of mounting an automatic unloading valve, set to operate at 35 lb. per sq. in., and a safety valve which operates and releases at 30 ± 2 lb. per sq. in. The function of the automatic unloader is to trip a valve in the compressor and so relieve the load on the engine when the volume of air used is less than the volume of air compressed.

Silica-Gel Beds.

Each of the two silica-gel beds (see Fig. 3) consists

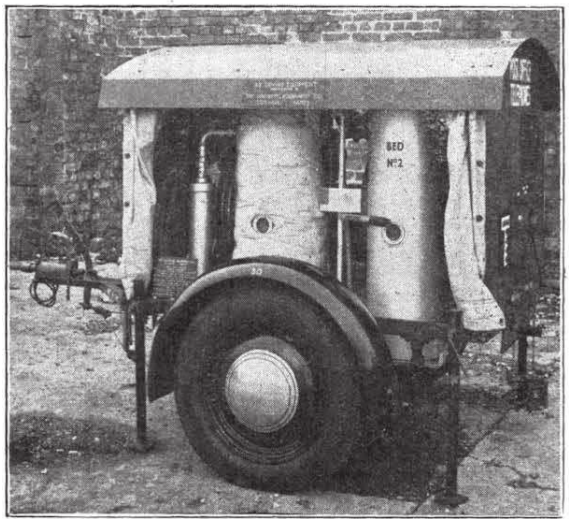


FIG. 3.—SILICA-GEL BEDS SIDE OF THE DESICCATOR.

of a cylindrical mild steel drum with a small glass window at a central position. Each bed contains 70 lb. of plain silica gel and also, in a perforated container behind the small window, 1 lb. of silica gel that is coloured, for indicating purposes, with cobalt chloride. When dry, the familiar cobalt blue colour is visible through the window, but as the silica gel adsorbs moisture the colour changes to pink. A colour-comparison guide is provided adjacent to the window as a safeguard to indicate when the bed should be reactivated. The colour guide is divided into four areas, ranging from blue to pink and clearly showing the safe and unsafe colour tints.

Although each bed has been designed to cater for the maximum volume of air that may be passed through it in a continuous run of eight hours, considerable periods may elapse between occasions of use and the particular moisture content of either bed may be unknown to an individual user. Hence, the provision of colour-indicating windows is considered to be a justifiable precautionary measure.

During the air-drying cycle of operation the air passes through each bed from the bottom to the top, while during the reactivating cycle the direction is

reversed. This ensures that the air, immediately before its entry into the cable, emerges from that part of the silica-gel bed which has received the most thorough reactivation and so minimises the risk of passing even a relatively small volume of damp air into the cables.

Change-over Valves.

The change-over valves consist, in essence, of a cylindrical block of mild steel containing two passageways and housed within a casing provided with four suitably disposed ports. The two valves are coupled together and operated by a single change-over lever that swings through an arc of 90°.

Heat-Exchanger.

Although the reactivation of the adsorbing agent could be achieved by the direct use of the engine exhaust-gases, numerous deleterious effects would result. The employment of a simple heat-exchanger overcomes this major disadvantage without appreciable loss of efficiency.

The heat-exchanger, which is illustrated in Figs. **4** and **5**, consists of a pack of copper plates clamped between cast iron headers which incorporate the inlet and outlet ports. Each plate has grooves cut in both faces, the grooves in one face being at right-angles to those in the other face. Each set of grooves terminates in marginal slots, one on each side of the plate, which, as the plates are assembled, form four separate passages connected into pairs by the grooves. The hot exhaust gases pass into one such passage, through the grooves in the plates, heating the plates in passing, and then to the other passage and out. The air to be heated is fed into the third passage, through the transversely cut grooves, receiving heat from the plates, and thence to the fourth passage and out. Fig. **4** shows the various components and the routes taken by the two gases. All the plates are marked to ensure replacement in the correct position and sequence, should the heat exchanger be dismantled for maintenance or cleaning.

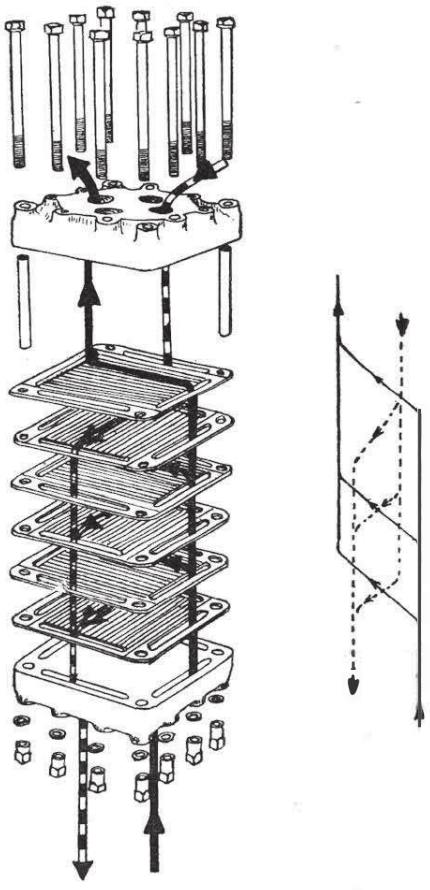


FIG. 4.—EXPLODED SKETCH OF HEAT-EXCHANGER.

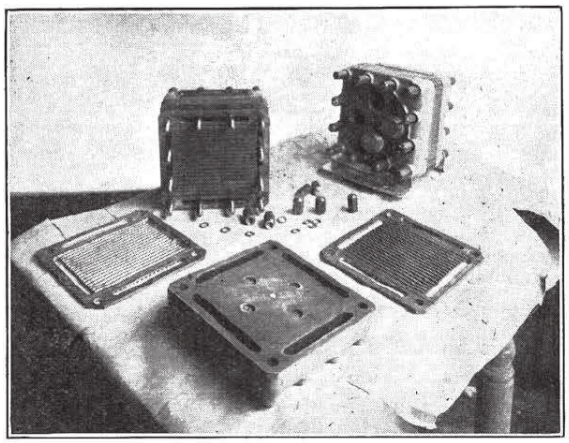


FIG. 5.—THE HEAT-EXCHANGER COMPONENTS AND ASSEMBLY.

To ensure the minimum loss of heat during the reactivation cycle, the hot pipes are permanently wrapped with asbestos tape and a heat-retaining jacket is provided around one of the silica-gel beds (see Fig. 3). The jacket is changed over to the other silica-gel bed when the latter commences its reactivation cycle.

After-Coolers.

To increase the relative humidity of the compressed air and so facilitate its drying, the air is cooled immediately after being compressed by being passed through a coil of gilled tubing mounted on the compressor and around the fan. A further cooling coil of copper tubing ensures that even after the apparatus has been running for several hours the temperature of the air delivered to the cables is not appreciably higher than the ambient temperature.

Performance.

The moisture-adsorbing performance of the unit is shown in Fig. **6**, and while this possibly may be regarded as a laboratory result, a series of practical tests was also made. The performance of the units under these critical, but practical, conditions was ascertained by the following test. The conductors in a 157-yd. length of 104 pr./10 lb. P.C.Q.T. cable were joined together in series and connected to a high-voltage megger and insulation resistance measure-

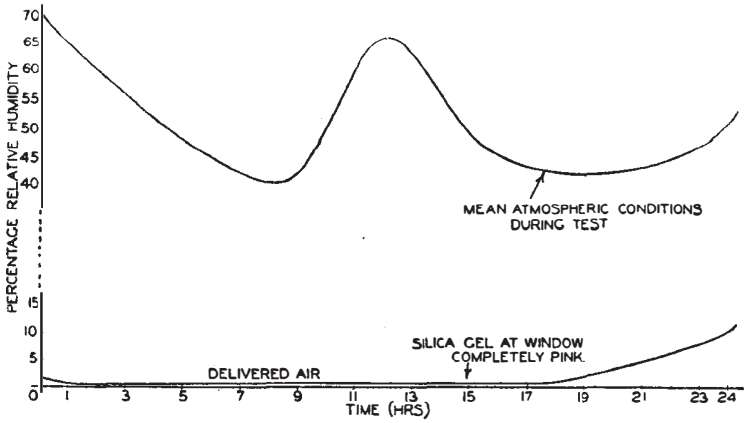


FIG. 6.—MOISTURE ADSORBING PERFORMANCE AS INDICATED BY VARIATION OF RELATIVE HUMIDITY OF AIR DELIVERED WITH RUNNING TIME.

ments taken. A carefully measured quantity of water was then injected into the centre of the cable through a suitable orifice. The dry air from the desiccator was then fed into one end of the cable and allowed to escape to atmosphere at the other. The results of a series of such tests are shown in Fig. 7. Although the volumes of water injected into the cable are probably very much greater than would be expected to be present under breakdown conditions, it is considered that the results clearly indicate the performance that may be achieved by the employment of such a desiccator in temporary restoration of faulty cable.

Conclusions.

The delivery capacity of the desiccator is calculated to be adequate for drying out in a minimum amount of time, either a 6-tube coaxial-type cable or two carrier or three air-spaced paper-core-type cables of the largest size. The time factor is governed primarily by the pneumatic resistances of the cables, together with the need to maintain the pressure at a fairly low value. It is concluded, however, that desiccators with a smaller output would produce further economies by catering for the average requirements rather than for the worst conditions.

Acknowledgments.

It is desired to express appreciation of the co-operation given by the Magnetic Equipment Co., Cosham, Hants., in the production and manufacture of these units which are believed to be the first of their particular type, and for the many suggestions made in connection with them.

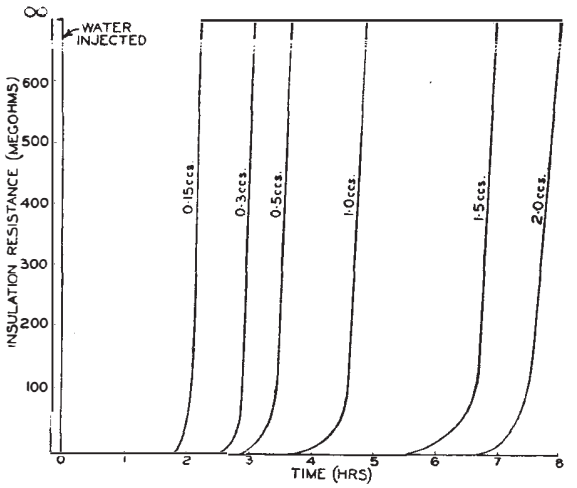


FIG. 7.—VARIATION OF INSULATION OF CABLE WITH RUNNING TIME OF DESICCATOR DURING TESTS.

Book Review

" Television Explained." Third Edition. W. E. Miller, M.A.(Cantab.), M.Brit.I.R.E. The Trader Publishing Co., Ltd. 104 pp. 75 ill. 5s.

This is a revised and enlarged edition of the handy little book first reviewed in this Journal some two years ago (Vol. 40, p. 178). Some of the earlier shortcomings of the book have been rectified ; in particular, receiver maladjustments are now illustrated by means of an excellent series of photographs of the television screen under various conditions. The picture with the controls said to be correctly set may be criticised, however, on the grounds that it is too deep and too wide, the black and white edging to the picture being obscured by the mask. Although, in fact, many viewers adjust their receivers in this way so as to enlarge the centre of the picture, it is not correct to do so and may lead to the loss of important parts of the picture such as the sub-titling on foreign films.

The major part of the additional space available in this edition has been used to allow a larger and more easily readable type, but many sections have also been expanded and new material has been added. In particular, the text now deals with the reception of signals from the Birmingham transmitter as well as Alexandra Palace. The vestigial sideband characteristic of the transmission from Sutton Coldfield is explained ; this shows a saving of about 2 Mc/s in the bandwidth of the transmitted R.F. spectrum as compared with the double sideband transmissions from Alexandra Palace. The modified form of receiver characteristic necessary for dealing with the vestigial sideband transmissions is also fully explained.

Up-to-date additions to the text include a brief description of a projection type receiver and the latest methods of generating the E.H.T. supply for the cathode ray tube. A very useful Appendix describes the " Test Card C " radiated daily by the B.B.C., and the way in which it can be used to check the performance of a receiver in respect of frequency response, linearity of scan, uniformity of focus, etc.

Those who found the earlier edition useful and who wish to bring their knowledge of the subject up to date will do well to study this new edition ; those who are new to the subject will find the book a valuable foundation upon which to base their studies.

T. K.

National Trunk Dialling

R. W. GIBSON, A.M.I.E.E.†

U.D.C. 621.395.341.4 : 621.395.332.3

This article discusses the dialling problems arising from the mechanisation of national trunk switching centres, and proposals for the routing of trunk traffic are advanced. A résumé of the existing national trunk network is given and the principles to be employed under trunk mechanisation are described.

Introduction.

A TRUNK call may be defined as any connection for which the normal charge is greater than 4 unit fees. It is usual, within the Post Office, to distinguish between two types of trunk call, namely, demand or long-distance calls which are controlled only at trunk exchanges, and toll or short-distance calls which may be controlled at any exchange.

While some trunk traffic is at present completed automatically, the objective of trunk mechanisation is that a controlling operator at a trunk exchange shall be able to complete any connection by dialling and without the assistance of any other operator. This objective calls for a considerable extension of the present trunk dialling facilities, and as some connections may involve two or more trunk circuits, it also requires the provision of tandem dialling facilities.

Outline of the Existing National Trunk Network.

The existing national trunk network is based on the division of the country into a number of basic areas, termed Group Areas. One exchange in each of these areas, usually the largest or most centrally situated, is selected as the Group Centre. This Group Centre acts as a collecting and controlling centre for all trunk traffic originating in the area and, in general, all trunk traffic incoming to subscribers in the area is routed through the Group Centre. Ultimately it is envisaged that there will be some 300 Group Areas, each of approximately 15 miles radius round the Group Centre. When all local exchanges in the area have been converted to automatic working there will normally be only one manual board in the area, namely that at the Group Centre. Thus, in addition to handling trunk traffic, the Group Centre manual board will also be used for assisting subscribers on their local calls.

The remaining exchanges in a Group Area are known as Minor or Dependent exchanges. A Minor exchange is one which has a direct route to the Group Centre, while a Dependent exchange obtains access to the Group Centre via a Minor exchange. Thus any subscriber in the area may be connected to the Group Centre over a routing involving not more than two junctions. Further, although it is impracticable to provide direct junctions between all Minor and Dependent exchanges, the interconnection of any two subscribers is readily achieved. Thus, in addition to acting as a controlling centre for trunk traffic, a Group Centre also serves as a switching centre for traffic circulating within the area. Ultimately, when all exchanges have been converted to automatic working, a large proportion of this traffic will be completed automatically by subscribers, and the appropriate fee recorded by the use of multi-metering equipment.

The large number of exchanges involved makes it uneconomical and impracticable to provide direct connections between all Group Centres. Thus larger units, termed Zones, are formed, each consisting of a number of Group Areas. One Group Centre, suitably situated, is selected in each Zone to serve as a trunk switching centre. These exchanges are known as Zone Centres. Direct connections are provided between a Zone Centre and all Group Centres in the Zone, and Zone Centres, with few exceptions, are fully interconnected with each other. In those cases where the Zone Centre is not fully interconnected, the Group Centres in such Zones will have access to a fully interconnected Zone Centre in addition to the normal home Zone Centre. Thus a Zone Centre acts as a switching centre for trunk traffic circulating within the Zone and also for traffic passing from one Zone to another. In addition, a Zone Centre functions also as a Group Centre for traffic originating or terminating in its own Group Area.

The division of the national network into Groups and Zones readily permits the interconnection of any two subscribers on a link-by-link basis, the fundamental routing being: Minor—home Group Centre—Zone Centre—Zone Centre—terminal Group Centre—Minor. In the extreme case two further links, Minor—Dependent, may be included. The present transmission plan is based on the following standards of transmission performance: Dependent or Minor—Group, 4·5 db. loss; Group—Zone, 3 db. loss; and zero loss between Zone Centres. With such a transmission plan, the overall transmission loss between terminal exchanges in any trunk connection should not exceed 15 db.

Present National Trunk Dialling Facilities.

At present, the only standard signalling system available within the P.O. network for providing dialling facilities on circuits routed via H.F. lines, is the P.O. 2 V.F. system. This is, in principle, a "signalling on speech path" system. It employs signalling frequencies in the voice range which are transmitted over the speech path, and may be used on any circuit, physical or H.F., which meets normal transmission requirements. The application of 2 V.F. working has so far been confined to circuits interconnecting Zone Centres, and the majority of such circuits employ this method of working.

With the original design of 2 V.F. equipment, the time required to effect the seizure of an incoming relay set and set up circuit conditions to accept impulses, precludes selector level access to a 2 V.F. link, as in this case the major part of the available inter-train pause period is taken up by the rotary search time of the selector. Hence, with the original design of 2 V.F. equipment, tandem dialling

† Assistant Engineer, Telephone Development and Maintenance Branch, E.-in-C.'s Office.

is not possible over connections involving more than one 2 V.F. link, and present dialling facilities are confined to circuits outgoing from a Zone Centre manual board, with limited access to the local automatic network beyond the terminal Zone switching centre.

For short-distance trunk circuits routed via audio cables, dialling facilities may be provided by loop or battery dialling. Battery dialling, however, is unsatisfactory over 4-wire amplified circuits, due to the relatively high capacitance of the signalling path, and is generally regarded as obsolescent. The dialling range with loop dialling is restricted, and although the range may be increased by the use of impulse regenerative relay sets at switching centres, its application in the trunk network is limited and mainly confined to single-link working, such as Group-Zone and Zone-Group connections. Loop dialling, however, is the standard method of signalling for local junction networks, namely Dependent-Minor-Group routings.

For the longer audio circuits, a long distance, direct current impulsing system, known as L.D.D.C. or system D.C.1, was developed.[1] The application of this system was mainly confined to the London Toll network, and for new work will be superseded by the single commutation, direct current impulsing system, known as S.C.D.C. or System D.C.2.[2]

Generally speaking, trunk dialling facilities are at present restricted to connections involving a single trunk link, and connections involving more than one trunk link are established on a link-by-link basis with the assistance of operators at the intermediate switching centres.

Routing Principles under Trunk Mechanisation.

It has been decided that, under trunk mechanisation, the present principle of link-by-link working will be retained and, as demand traffic will continue to be originated and controlled by an operator—normally at a Group Centre—the fundamental trunk routing will remain as at present, namely, originating Group Centre—Zone Centre—Zone Centre—terminal Group Centre. For large cities, the volume of originating trunk traffic may make it advantageous to provide more than one manual board and traffic will then be handled at suitably situated exchanges, termed Control Centres. Each Control Centre will be directly connected to the main trunk switching centre, normally a Zone Centre, and thus the fundamental trunk routing in these cases becomes: Control Centre—Zone Centre—Zone Centre—terminal Group Centre.

With the retention of link-by-link working it becomes necessary to route trunk traffic automatically through the intermediate switching centres. This may be effected by using either a translator or non-translator system, which are analogous to the director or non-director system of local automatic working. It has been decided to adopt a non-translator system. Thus traffic will be routed on a non-director switching basis, and controlled directly by the routing digits dialled by the controlling operator.

[1] I.P.O.E.E. Printed Paper, No. 178.

[2] To be described in the next issue.

The numbering schemes to be employed for the routing of operator-controlled traffic under trunk mechanisation will be individual to the trunk switching centres and not form part of a national numbering scheme.

If, at some future date, subscriber-to-subscriber trunk dialling is introduced, a national numbering scheme and a translator trunk dialling system may be introduced. Their introduction, however, will not be prejudiced by the arrangements adopted for operator trunk dialling.

Signalling Systems under Trunk Mechanisation.

To meet the requirements of trunk mechanisation, the signalling systems used on trunk circuits must meet the following basic requirements:—

(i) The system must permit of seizure from a selector level.

(ii) The seizure time must be small, in order that the controlling operator may dial at normal speed without excessive pauses between digits.

(iii) The system must provide tandem-dialling facilities.

The systems which will be used initially to provide dialling facilities under trunk mechanisation are as follows:—

(*a*) 2 *V.F.* (*System A.C.*1).—Two types of equipment may be used, namely, equipment of existing design and type as at present in service, and a later design[3] which has been developed primarily to provide selector level access. An important difference between the two types of equipment is the inclusion of an impulse regenerator in the outgoing selector level relay sets of the later design, primarily to reduce the effective seizure time of a 2 V.F. link when seized from a selector level, where the major part of the inter-train pause is taken up by the rotary search time of the selector.

(*b*) *Single Commutation Direct Current Impulsing* (*S.C.D.C., System D.C.*2).—The application of this system is confined to audio circuits. Briefly, impulsing is effected by the transmission of double current signals, and supervisory signalling by earth return leg signals. Impulse distortion correcting elements are included in both the outgoing and incoming relay sets, and these are manually adjusted to take up the distortion introduced by relay contact transit times, and also by local impulse repetition at switching points. Within the limits of testing error S.C.D.C. may be termed a "controlled distortion" impulsing system.

(*c*) *Long Distance Direct Current Impulsing* (*L.D.D.C., System D.C.*1).—Where already existing, L.D.D.C. working may be retained, but this system is now obsolescent and will be replaced for new work by S.C.D.C.

(*d*) *Loop Dialling.*—The use of loop dialling will be confined to the shorter distance Group or Control Centre—Zone and Zone—Group circuits, routed via audio pairs.

Ultimately, it is envisaged that trunk dialling facilities will be provided by an A.C. signalling system for long-distance circuits routed via carrier or

[3] To be described in a forthcoming issue.

coaxial cables, and by S.C.D.C. for the longer audio circuits and short-distance audio circuits routed via amplified circuits. The use of loop dialling will thus be confined to short distance unamplified circuits and the local junction networks. As stated previously, dialling facilities will be provided initially over H.F. circuits by 2 V.F. equipment, the outgoing selector level relay sets of which will include an impulse regenerator. Consideration is being given, however, to the possibility of obviating the need for this regenerator, in which case the ultimate A.C. signalling system may take the form of a " controlled distortion " system.

The Impulsing Problem.

With the decision to route national trunk traffic on a non-director switching basis, the fundamental impulsing problem is the response of the selector switching equipment—at all exchanges involved in a connection, from the first trunk switching centre down to the terminal Minor or Dependent exchange in the local network—to the routing digits dialled by the controlling operator at the originating Group Centre.

A known maximum amount of impulse distortion may be introduced between the output of a dial and the output of the A relay of a final selector, and this margin may be distributed over the trunk and local junction networks. The impulsing problem thus resolves into an examination of the available distortion margin; the distribution of this margin over the various links involved in a trunk connection; and, if the margin is insufficient to ensure reliable operation of all equipment, the impulsing aids, such as impulse regeneration or correction, that must be introduced and the siting of such equipment to the best advantage.

With link-by-link working, and when the method of signalling is other than loop dialling, line impulses are converted at the incoming trunk relay sets at each switching point to loop impulses which control the selector equipment at the switching centre. The loop impulses are re-converted to the appropriate line signals at the outgoing relay set associated with the following link. Thus the impulse distortion introduced by a trunk connection obviously depends on the number of links involved in the connection. While the fundamental routing under trunk mechanisation involves three trunk links, namely Group—Zone—Zone—Group, an analysis of trunk demand traffic has shown that some 53 per cent. of the traffic involves only one trunk link and some 3 per cent. is completed over two trunk links. On the other hand, the objective of trunk mechanisation is that ultimately all connections be established automatically, and thus connections involving three trunk links must be considered, even although the actual volume of traffic concerned is small. Further, the present arrangements for alternative routing will be retained under trunk mechanisation, whereby, if a call cannot be established over the recognised primary routing, due to congestion of any trunk link, the controlling operator may attempt to set up the connection over an alternative or secondary routing. Under these conditions the routing may involve four trunk links, namely Group—Zone—Zone—Zone—Group, and this present study of the trunk dialling problem has been based on this condition.

Trunk traffic to Minor or Dependent exchanges in the terminal Group area may involve a maximum of two local junctions, namely Group-Minor-Dependent routings.

The Available Impulse Distortion Margin.

The maximum amount of impulse distortion that may be allowed to occur on any connection is the difference between the output of the impulse sender and the operating requirements of the terminal selector equipment. In the problem under consideration the impulse source will be the controlling operator's dial, or equivalent impulse sender, with normal limits of 9-11 i.p.s., 63-70 per cent. break, and the terminal equipment will be a final selector at the objective Dependent exchange, which may incorporate equipment of any type.

Typical impulsing elements of 3,000-type selector equipment (equipment incorporating 3,000-type relays and pre-2,000-type selector mechanisms) and 2,000-type selector equipment (equipment incorporating 3,000-type relays and 2,000-type selector mechanisms) are illustrated by Fig. 1. Pre-3,000-type equipment

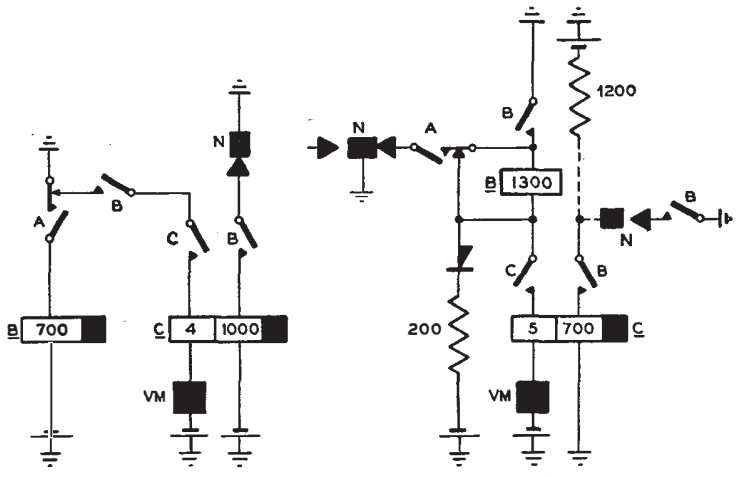


FIG. 1.—IMPULSING ELEMENTS OF SELECTORS; (*a*) 3,000-TYPE EQUIPMENT, (*b*) 2,000-TYPE EQUIPMENT.

(equipment employing contractors' type relays and pre-2,000-type selector mechanisms) may, in general, be considered as similar to 3,000-type equipment.

The operating requirements of selector equipment are governed by:—

(*a*) the operate and release times of the selector magnets.

(*b*) the impulse holding performance of the B and C relays.

The performance of these items, in terms of the

selector A relay output, together with the limits of impulse output for an operator's dial, are illustrated by the target diagram of Fig. 2, from which it will be

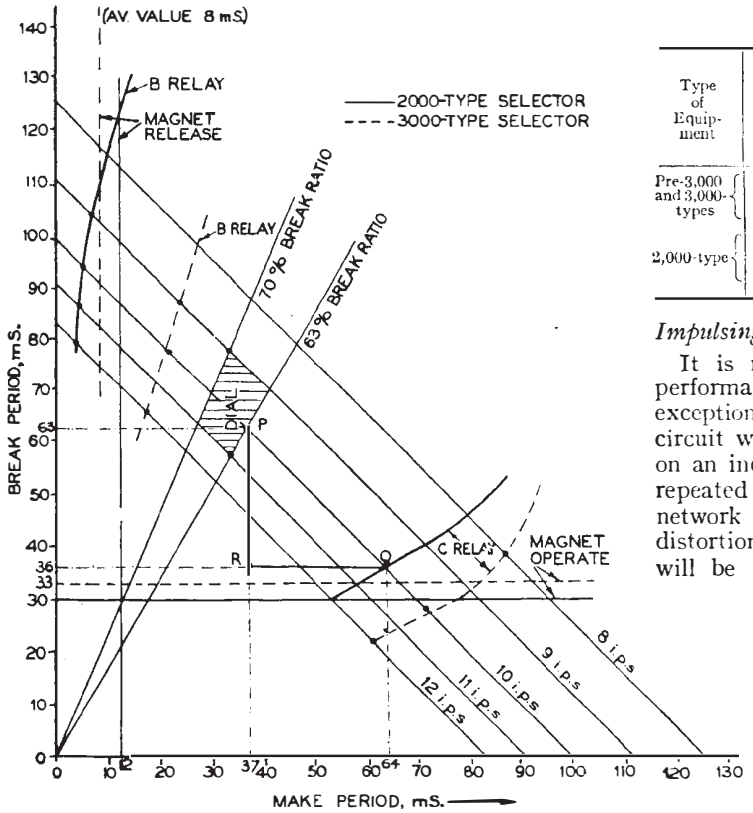


FIG. 2.—SELECTOR TARGET DIAGRAM.

seen that, within the limits of 9-11 i.p.s., the response of selector equipment is governed by the following :—

2,000-type equipment—magnet release time and C relay impulse holding performance.

3,000-type equipment—B relay impulse holding performance and magnet operate time.

The distortion that may be introduced between the impulse source and the terminal selector equipment may be readily obtained from the target diagram. For example, consider an impulse speed of 10 i.p.s. The co-ordinates of the point P, 63 mS break period, 37 mS make period, represent the output of the impulse source, and the co-ordinates of the point Q, 36 mS break period, 64 mS make period, represent the operating requirements of 2,000-type selector equipment. Hence the distortion margin, in terms of the amount by which the make impulse output of the source may be increased, is given by RQ, namely 64 — 37 = 27 mS. It is usual to express the distortion margin as positive or negative, representing the amount by which the make impulse output of the source may be increased or decreased.

From Fig. 2 it will be seen that, within the limits of 9-11 i.p.s., the margin is least at 11 i.p.s. and also that on the negative side it is governed by the requirements of 3,000-type equipment and on the positive side by 2,000-type equipment. The distortion margin is summarised in Table 1, the limiting values being shown in bold type.

TABLE 1

Overall Impulse Distortion Margin.

Type of Equipment	Dial Speed, i.p.s.	Maximum Make, mS. Dial Output	Selr. Requirements	+ve Distortion Margin	Minimum Make, mS. Dial Output	Selr. Requirements	−ve Distortion Margin
Pre-3,000 and 3,000-types	11	33·5	58	+24·5	27·5	19	**− 8·5**
	10	37	67	+30	30	21·5	**− 8·5**
	9	41	78	+37	33·5	24·5	**− 9**
2,000-type	11	33·5	58	**+24·5**	27·5	12	−15·5
	10	37	64	+27	30	12	−18
	9	41	71	**+30**	33·5	12	−21·5

Impulsing Performance of Local Junction Networks.

It is now necessary to examine the impulsing performance of local junction networks. With the exception of circuits employing loop dialling, a trunk circuit will terminate at the terminal Group Centre on an incoming relay set, and loop impulses will be repeated from this relay set over the local junction network to the objective exchange. The impulse distortion occurring at the terminal Group Centre will be least when forward-holding principles are employed at this exchange, as this avoids a further impulse repetition stage between the incoming trunk relay set and the local junction network. On the other hand, many Group and Zone Centres will employ backward-holding, and thus this condition dictates the performance and has been assumed.

In the local network, impulse distortion may be introduced at each impulse repetition stage, the magnitude and sense depending on such factors as relay adjustment, battery voltage and junction characteristics, namely resistance, leakance and mutual capacitance, and also on whether the junctions are amplified or unamplified circuits. A detailed examination of the factors affecting impulse distortion will not be considered here as this has been fully covered elsewhere.[4]

As later considerations suggest that it may be advantageous to replace loop dialling on amplified circuits by a system in which the distortion is controlled, separate consideration will be given to the distortion introduced by local junction networks with :—

(*a*) Loop dialling over both amplified and unamplified circuits.

(*b*) Loop dialling over unamplified circuits only.

Also, it is convenient at this stage to consider the distortion occurring with a single loop-dialling junction and also with no junction, i.e. the distortion introduced by the A relay of a final selector or impulse regenerative relay set situated at the terminal trunk exchange.

The distortion introduced by local junction networks is given in Table 2, and for the purpose of this

[4] I.P.O.E.E. Printed Paper, No. 184.

table it has been assumed that impulses are repeated from an incoming trunk relay set with a 2 μF + 100 ohms spark quench across the impulse repeating contact.

TABLE 2

Local Network Distortion.

Type of Junction and Resistance	Adverse limits of distortion introduced by the local network, mS.	
	+ ve	− ve
No Junction	+ 3	+1
Single Junction (0-1,500 ohms)		
(*a*) Amplified only	+18	—
(*b*) Unamplified only	+13	−5·5
(*c*) Amplified and Unamplified	+ 18	−5·5
Two Junctions (0-800 plus 0-800 to 3,000-type terminal exchange)		
(0-800 plus 0-1,500 to 2,000-type terminal exchange)		
(*a*) Amplified only	+21·5	—
(*b*) Unamplified only	+16·5	−5·5 for 3,000-type
(*c*) Amplified and Unamplified	+21·5	−8 for 2,000-type terminal exchange

For a routing involving junctions of 0-800 plus 0-1,500 ohms to a 2,000-type terminal exchange, the higher negative distortion (−8 mS.) resulting from the greater resistance of the second junction, is more than offset by the wider distortion margin available with 2,000-type selector equipment.

Possibility of Straightforward Dialling System.

A straightforward dialling system involves the direct repetition of impulses at each switching point, without impulse regeneration or correction. Thus the distortion margin available to the trunk network will be that remaining after the requirements of the local junction network have been satisfied. From the values given in Tables 1 and 2, it will be seen that :—

The minimum overall distortion margin available = +24·5 to −8·5 mS.
Local network distortion, 2-junction route, amplified/unamplified condition = +21·5 to −5·5 mS.
Distortion margin available for the trunk network = +3 to −3 mS.

If, however, loop dialling in the local network is restricted to connections involving only unamplified junctions, the distortion margin available for the trunk network is increased to +8 to −3 mS. As mentioned previously, a maximum of four trunk links may be involved in a trunk connection, and the question arises whether it is possible to design and maintain trunk signalling equipment to meet such narrow margins of distortion.

It is possible, by the use of suitable components, together with adjustable corrector elements which can be arranged to decrease or increase the impulse make period within certain limits, to design equipment such that, within the limits of testing error and assuming constant exchange battery voltage, no distortion is introduced at the local impulse repetition stages. Signalling systems designed on these lines may be termed " controlled distortion " systems. On the other hand, there will always be variations in the impulsing performance of equipment due to the effect of a number of variables, such as drift of adjustments, variations of voltage supplies and, for A.C. signalling equipment, variations of signal level and frequency. Modern V.F. receivers, however, are capable of giving an impulsing performance of the order of ± 1 mS. distortion over the normal ranges of line T.E., voltage and tone supplies.

Allowance must also be made for the tolerances for maintenance testing. It is desired to test equipment *in situ*, and thus the routine test limits must take into account the change in impulsing performance resulting from a change of battery voltage, or otherwise, readjustment of equipment would be necessary if maintenance testing happened to coincide with periods of adverse voltage. With regard to the latter, it is usual at Zone Centres to have " Divided Battery Float " power plant which gives a comparatively stable voltage, but at many Group Centres C.E.M.F. cell switching schemes are employed, with which voltage variations occur quite frequently.

An approximate estimate of the distortion likely to occur on a trunk connection, assuming straightforward dialling with " controlled distortion " impulsing systems, is given in Table 3. For the purpose of this table, advantage has been taken of the closely controlled voltage conditions at Zone Centres, but any characteristic bias, that is bias due to the characteristics of signalling systems, has been ignored.

TABLE 3

Trunk Network Distortion with Straightforward Dialling.

Trunk Routing	Distortion, mS.			Overall Distortion Range, mS.
	Line Relay	Group Centre D.C. Repetition	Zone Centre D.C. Repetition	
G-G	±1	±2	—	6
G-Z-G	±2	±2	±0·5	9
G-Z-Z-G	±3	±2	±1	12
G-Z-Z-Z-G	±4	±2	±1·5	15

As shown previously, the distortion margin remaining for the trunk network, after meeting the requirements of a 2-junction local network routing, involving both amplified and unamplified junctions, is +3 to −3 mS., i.e., an overall range of 6 mS. It will be seen from Table 3 that this precludes dialling over two or more trunk links on a straightforward dialling basis. Further, even assuming that loop dialling in the local network is restricted to unamplified junctions, the distortion margin available to the trunk network is +8 to −3 mS., an overall range of 11 mS., and this is insufficient to meet the requirements of a 4-link trunk connection, which requires an overall range of 15 mS.

Summarising, it will be seen that the impulsing requirements of junctions, selectors and impulse repeating equipment in existing local networks preclude the use of a straightforward dialling system for the trunk network. Dialling over one trunk link may be possible, but to permit dialling over two or more trunk links some reduction is necessary in the distortion introduced by the local networks. This may be achieved ultimately by confining loop dialling in the local network to routings involving a single unamplified junction, and employing a controlled-distortion D.C. impulsing system on all amplified circuits and routings involving two junctions. In the meantime it would be necessary

to restrict the trunk dialling range to connections involving a single loop dialling junction beyond the terminal trunk switching centre.

Alternatives to Straightforward Dialling.

A straightforward dialling system being impracticable, it is obvious that some form of impulsing aid must be introduced at some or all of the switching points involved in a trunk connection. These impulsing aids may be either impulse regenerators or impulse correctors. With impulse regeneration, the speed and ratio of the transmitted impulses are independent of that of the received impulses. As the speed of the received impulses may be greater than that at which they are transmitted, impulse storage is necessary, and it is the usual practice to store a complete impulse train.

With impulse correction, impulses are transmitted, with negligible delay, at the same speed as that at which they are received, but with corrected impulse ratio or corrected make or break pulse periods. In the simplest form of impulse corrector a fixed impulse speed is assumed, and the duration of the transmitted make or break pulse periods is controlled to relatively close limits. This type of fixed time base corrector suffers from the disadvantage that the ratio of the transmitted impulses varies at different impulse speeds. It is possible, for example, by measuring the total break plus make period of the received impulses, to design a corrector such that the ratio of the transmitted impulses is independent of the impulse speed, but such correctors are relatively complex and costly items. Under the conditions existing in the Post Office network, impulse regeneration, with the complete storage of an impulse train, is preferred to the use of impulse correctors. A description of the present standard impulse regenerator has been given in a previous article.[5]

The need for some form of impulsing aid in the trunk network having been established, it is now necessary to consider the siting of such equipment to the best advantage.

Impulse Regeneration at all Intermediate Trunk Switching Centres.

The inclusion of an impulse regenerator in all trunk circuit relay sets outgoing from selector levels is attractive from the signalling and impulsing aspect in that it offers the following advantages :—

(*a*) The impulse distortion introduced by a trunk circuit routed via an outgoing relay set with regenerator will be independent of that introduced by any preceding circuit. Thus any number of links may be connected in tandem and yet each link may be considered as a self-contained circuit from the impulsing aspect.

(*b*) It permits the major portion of the available inter-train pause period to be taken up by preceding switching operations, as the delay introduced by the regenerator between the receipt and transmission of the first impulse train is available for the seizure of a 2 V.F. link and the preparation of the distant equipment to receive impulses. This is an important advantage in relation to the existing 2 V.F. signalling system in which the time taken to seize the distant equipment and set up impulsing conditions leaves insufficient time for selection over large groups of trunk circuits. For this reason a regenerator has been included in the outgoing selector level relay sets of the equipment which will be used under trunk mechanisation.

On the other hand the fitting of regenerators at all intermediate trunk switching centres is open to objection on the following grounds :—

(*a*) It increases the maintenance attention required on the outgoing trunk relay sets.

(*b*) The present impulse regenerator is inferior to an operator's dial as an impulse source, its upper speed limit being 12 i.p.s. The effect of this is to reduce the distortion margin given in Table 1 from −8·5, +24·5 mS. to −7, +19·5 mS. It may be possible to overcome this particular difficulty by reducing the nominal speed to 9 i.p.s. so as to reduce the upper limit to 11 i.p.s.

(*c*) Delay is introduced in setting up a connection The greatest delay will be introduced by the first regenerator in the connection when dialling is carried out quickly, due to the lengthening of the inter-train pause periods. This may amount to 0·5 seconds per digit, say 4 seconds for an average of 8 digits. To this must be added the delay between receipt and transmission of the first digit, approximately 1·5 seconds, which is introduced by each subsequent regenerator in the connection. This delay of 1·5 seconds may be reduced by eliminating the initial inter-train pause before sending. The importance of the overall delay is minimised if allowance is made for the fact that some 53 per cent. of the trunk traffic passes over only one trunk link, and hence will encounter only one regenerator in the trunk network. Also, as long as cord-type switchboards remain in use, there will be a proportion of direct circuits available, and these need not include regenerators. Ultimately, cordless type switchboards will be employed and a greater use will be made of key-senders instead of dials, on which the pause between digits can be made sufficiently long to permit switching and signalling operations to be effected without artificially lengthening the pause. Under these conditions the delay introduced by regenerators between the receipt and transmission of the first digit may not be noticed.

The inclusion of a regenerator in all outgoing trunk circuit selector level relay sets, however, does not of itself offer a solution to the trunk dialling problem. As shown previously, an overall distortion margin of only 6 mS. remains for the trunk network after the requirements of a local junction routing involving two junctions, amplified or unamplified, have been met. This margin is available to each link involved in a trunk connection, as the inclusion of a regenerator

[5] *P.O.E.E.J.*, Vol. 30, p. 261.

in the outgoing relay sets results in each link becoming, from the impulsing aspect, a self-contained circuit. To meet the requirement, however, that the distortion introduced by a trunk link should not exceed a range of 6 mS, it would be necessary to employ "controlled distortion" impulsing systems on all trunk circuits. Failing this, further impulse regeneration will be necessary, either at the terminal trunk switching centre or at some subsequent stage in the local network.

Impulse Regeneration at Terminal Trunk Switching Centres.

It is apparent that the maximum advantage will be obtained from impulse regeneration if the equipment is sited so that the distortion introduced by the local junction networks is not additive to that introduced in the trunk network.

It follows, therefore, that the ideal siting of impulse regenerators is on all local junction levels at terminal trunk switching centres, as this makes the whole of the impulse distortion margin available for the trunk network.

This siting of impulse regenerators has the added advantage of fitting in with the impulsing requirements of the local junction networks. In this connection, it is desired, as far as possible, to avoid the use of impulse regenerators at Minor exchanges, especially those of the U.A.X.7, 13 and 14 types, but the impulsing performance of the present type of auto-auto impulse repeating relay sets is such that some impulsing aid is necessary for connections involving three or four junctions. With the exception of Dependent-Dependent routings via a Minor exchange, all three- or four-junction routings in the local network would be assisted by impulse regeneration at the Group Centre.

Thus, while the fitting of impulse regenerators on all local junction levels at terminal trunk switching centres is attractive, it remains to be considered whether the distortion margin made available to the trunk network is sufficient, having regard to the performance of the signalling systems that may be used, to meet the most onerous routing conditions that may arise under trunk mechanisation without the need for impulse regeneration at any other trunk switching centre.

The signalling systems that will be available initially under trunk mechanisation have been discussed previously, and for Zone-Zone circuits are the 2 V.F. system and S.C.D.C. equipment. The use of the latter is confined to audio circuits, and as many of the Zone-Zone circuits at present routed via audio cables may be converted to H.F. working in the near future, the use of S.C.D.C. equipment on Zone-Zone circuits is unlikely, as early conversion to 2 V.F. working may be necessary. For 2 V.F. equipment, the outgoing selector level relay sets will incorporate an impulse regenerator, which, as stated previously, has been included primarily to reduce the effective seizure time of a V.F. link and not for reasons of impulsing performance. While this regenerator offers advantages from the impulsing aspect, in that each link may be considered as a self-contained circuit, future developments may obviate its need. In this event a non-regenerative, controlled distortion, V.F. impulsing system may be developed, and in order not to prejudice the introduction of any new signalling system developed on these lines, allowance should be made for the impulse distortion which may be introduced in the trunk network with such a system.

For Group-Zone and Zone-Group circuits, the signalling systems initially available will be 2 V.F., S.C.D.C., L.D.D.C. and loop dialling. The greatest distortion will be introduced when loop dialling is employed, and will be a maximum under amplified line conditions. Ultimately, it is hoped that S.C.D.C. working will be employed on all amplified circuits, but due to the large number of circuits involved it is impracticable at the present time to convert all loop dialling circuits to S.C.D.C. working. Further, in many cases, the additional accommodation required and power plant capacity, makes such conversion impracticable. Thus, it is essential to permit as extensive a use as possible of loop dialling on Group-Zone and Zone-Group circuits in order that existing dialling facilities and methods of working may be retained.

The distortion margin remaining for Group-Zone and Zone-Group circuits, after allowance has been made for the distortion that may be introduced by Zone-Zone circuits routed via a non-regenerative controlled distortion impulsing system, is insufficient to permit loop dialling over both Group-Zone and Zone-Group circuits should both be amplified. The margin does, however, permit loop dialling over a Group-Zone circuit, amplified or unamplified and of resistance up to 1,500 ohms, together with loop dialling over an unamplified Zone-Group circuit of resistance up to 800 ohms. Loop dialling is also permissible over circuits to the above limits when S.C.D.C. or 2 V.F. working is employed on the Zone-Zone circuits.

Where loop dialling is required on Zone-Group circuits which either have a resistance greater than 800 ohms or are amplified, impulse regeneration at the Zone Centre, in addition to the terminal Group Centre, will be necessary. With this exception, it is seen that the fitting of impulse regenerators on all local junction levels at terminal Group Centres offers an attractive solution to the trunk dialling problem, inasmuch as it permits the most onerous routing conditions that may arise under complete trunk mechanisation to be met with a non-regenerative trunk dialling system. Also, besides fitting in with the impulsing requirements of local junction networks, the proposal has the added advantage that ultimately no call, either trunk or local, need encounter more than one impulse regenerator on any connection.

Conclusion.

The objective of trunk mechanisation, namely that an originating operator at a Group Centre shall be able to establish any connection by dialling and without the assistance of another operator at any intermediate switching centre, calls for a considerable extension of the present National trunk dialling facilities. A straightforward dialling system, with the direct repetition of impulses at all switching points, is

not a practical proposition, as the character of existing local junction networks takes up the major portion of the available impulse distortion margin

The inclusion of impulse regenerators in all outgoing trunk circuit selector level relay sets is attractive It permits any number of trunk links to be connected in tandem, but does not offer a complete solution to the problem as further impulse regeneration, either at the terminal trunk switching centre or at some subsequent point in the local network, is still required.

The most satisfactory solution to the National trunk dialling problem is given by fitting impulse regenerators on all local junction levels at terminal Group and Zone/Group centres. By this means the impulse distortion introduced by the local junction networks is not additive to that introduced by the trunk network, and hence the maximum possible margin of impulse distortion is made available to the trunk network. This margin is sufficient to permit the most onerous routing condition that may arise under complete trunk mechanisation to be met with a straightforward trunk dialling network. At the same time, it permits the retention of loop dialling on circuits interconnecting Group and Zone Centres, which is an advantage from an economic point of view.

Acknowledgments.

Acknowledgments are due to colleagues in the Telephone Branch of the E.-in-C.'s Office for their assistance and many valuable contributions given in the course of preparation of this article.

Book Reviews

"Cathode Ray Tube Traces." Hilary Moss, Ph.D., A.M.I.E.E. *Electronic Engineering*, London, 1949, 66 pp. 52 ill. + 180 traces. 10s. 6d.

A series of articles, which appeared in *Electronic Engineering* some five years ago, forms the basis of this book. In it the author stresses the importance of the geometrical theory of the patterns which users of oscilloscopes have found of value; the means of production of time bases, linear or otherwise, are largely left to other books.

The Lissajous figure is well explained in the first chapter, but the rules given for determining the ratio of the frequencies of the two waveforms giving the figure could be improved. They admit of exceptions, where another does not, and the word "intersection" is used in one rule, where in practice it will be found to apply only to a line touching a curve. The chapter points out many interesting features of complex Lissajous figures, whose interpretation has several pitfalls, and concludes with the effect of pulse injection into one of the waveforms generating a Lissajous figure.

Linear time bases, so widely used in commercial C.R. oscilloscopes, provide the horizontal deflections in the second chapter, but even the most experienced users of commercial instruments can expect to find new features in the patterns shown.

Circular and spiral time bases are well dealt with; limitations in their production are not overlooked. The patterns show that radial deflection of circular time bases offers new possibilities in the presentation of some recurrent waveforms.

Complex waveforms are next considered and deductions made from symmetry conditions. Extensive series of patterns using a linear time base show 2nd, 3rd, 4th and 5th harmonic distortion. The same chapter gives "beat" waves very good attention, and lists expressions for some waveforms often met with in pulse communications. The last chapter deals with amplitude-modulated waves, and again introduces new presentations. Here, perhaps more than anywhere else, the reader will ask whether full advantage is always taken of the oscilloscope in examining waveforms so often met in telecommunications.

The book concludes with some worthwhile though simple appendices on the transient response of networks, the use of C.R.T.s and the production of the waveforms shown. The book is readable and instructive. It is well produced, except for the cover and, in all, justifies the bringing together of the otherwise separated articles.

J. R. T.

"Electronic Time Measurements." Massachusetts Institute of Technology. McGraw-Hill Publishing Co., Ltd, London. 538 pp. 383 ill. 42s.

This book, Volume 20 of the Radiation Laboratory Series, deals with systems for the accurate measurement of small repetitive time intervals, such as are required in precision ranging radar equipments and certain types of radio navigational aid, for example, Gee and Loran. Although most of the systems discussed are American, there are several descriptions of British, and one or two mentions of German equipment.

After a brief introduction, Chapter 2 summarises the various methods of distance and speed measurement using pulse-, phase-, and frequency-modulated waves, and also continuous waves. The next chapter reviews the technique of pulse time measurements.

Chapters 4 and 5 cover in rather more detail the production and measurement of fixed and movable time-markers.

Chapter 6 is concerned with the application of these circuits to systems, and describes a widely-used precision ranging system. The direct-reading Loran Indicator is also discussed.

Chapter 7 deals with manual measurements, in which the operator sets a marker to coincide with the incoming signal, and discusses the different types of marker and the errors involved. In the next two chapters automatic methods of performing the same task are considered, including the provision of "search and lock on" facilities for radar equipments.

Chapters 10 and 11 are concerned with special systems for the transmission of range and bearing information, principally by radio, using pulse-position modulation and tone-modulation techniques.

The last chapter discusses at length the technique of cancelling-out the unchanging part of a slowly-changing recurrent waveform. This has practical application in the detection by a radar system of a moving target in the presence of fixed targets.

Two features of the book which make reading somewhat difficult are the multiple authorship which results in some repetition and discontinuity and the highly specialised terminology.

The emphasis throughout the book is on complete systems, the principles of operation of the individual circuits employed to make up these systems being only briefly described; reference is frequently made to Volume 19 of the Radiation Laboratory Series on "Waveforms," for detailed information on the latter. For this reason the book will be of value chiefly to those concerned with the operation and design of the systems described, rather than to those interested in using similar techniques for other purposes.

A. H. F.

Introduction to Electronic Automatic Telephone Exchanges: Register-Translators

T. H. FLOWERS, M.B.E., B.Sc., M.I.E.E.†

U.D.C. 621.395.34 : 621.38 : 621.395.636.3

The operations of remembering an instruction and converting the instruction into an action to be performed are inherent in all telephone switching systems. In automatic telephone systems these actions are performed in a number of ways by a variety of different forms of apparatus, one of which is the register-translator which takes in a number of several digits, and sends out a number which may be different in one or more of its digits. This article describes some of the possible forms of all-electronic register-translators which can register, translate and send numbers. The next article will discuss trunking and selecting systems.

General.

A PREVIOUS article[1] has considered speech path switches in a fully electronic exchange system and the controlling signals which may be passed through them. It was assumed that a number of ranks of switches would be provided in each exchange, connections being made through the exchange by switches in each rank. Before discussing the setting of the switches it is preferred to consider (as is the purpose of this article) some possible forms of register-translator from which, in some selecting systems, the setting of the switches may be considered to start. Register-translators, as generally understood, are not essential to an automatic telephone system, and where used, they may differ widely in their design and perform a variety of different functions. Hence, generalisation is difficult, but it is thought the examples given in the following descriptions will convey some of the more general ideas and possibilities of all-electronic apparatus.

Preliminary Outline and Definitions

It is necessary first of all that the terms such as register and translator should be clearly understood. It is thought that this may be best accomplished by referring to the analogy between manual operating and the equivalent functions performed by a machine.

An operator, whether at an originating, a transit, or a terminal exchange, performs operations which may be regarded as divided into three categories :—

(*a*) The operator first of all registers in her mind an instruction which is given to her verbally by a subscriber or another operator. This memorising of an instruction, which is to be forgotten when acted upon and is therefore temporary, will be identified as the register function.

(*b*) The operator compares the instruction (*a*) with a set of permanent instructions, some of which are recorded in her own memory, some perhaps in printed form on a card index on her position, and in various other ways. From this comparison the operator derives the information concerning the next action which she must take. The combined comparison of the temporary with the permanent instruction to derive the next action to be taken will be defined as the translating function. The permanent instructions are permanent in the sense that they remain in existence until deliberately altered or destroyed by the Administration. The permanent instruction is the means by which the Administration controls the telephone service.

(*c*) The operator takes the action indicated in (*b*) and this is identified as the sending function.

No matter how a telephone system works, with operators or any kind of a machine, these operations can be traced to exist. When they are performed by a single piece of apparatus in an automatic exchange, that apparatus may be called a register-translator-sender, but is more commonly called a register-translator.

Machine operation has an influence on the basic operations which will now be examined. An operator can remember names as well as, and perhaps better than, numbers but a machine can conveniently remember only numbers. One of the first stages, therefore, in the conversion of a manual system to an automatic system is to convert all the subscribers' instructions into numbers. Secondly, an operator can use her intelligence to decide what action to take in abnormal circumstances. A machine has no intelligence, and the instructions for every possible circumstance must be built into the machine at the outset. Again, the action which an operator may take is largely based on information in the form of a number, but also includes communicating exchange names and taking other actions which are not in numerical form. The machine acts most readily by numerical information and the sending function of a register-translator is most conveniently arranged in that form.

What has been said so far can be illustrated from current practice by considering the familiar director as a register-translator. A director is given the wanted subscriber's exchange code and number, which it registers on mechanical switches, digit by digit, by the distinctive position of the wipers of each switch. The instructions which are permanently stored in the register are in the form of permanent wiring and refer only to the exchange code digits recorded on the register. The comparison between the registered digits and the "memory" is made by metallic contact between the register switches and the permanent wiring memory, and the translation is communicated directly in the form of digits which are sent out. The director is, therefore, a

† Staff Engineer, Research Station.

[1] T. H. Flowers. "Introduction to Electronic Automatic Telephones Exchanges: Speech Path Switches and Line Signalling." *P.O.E.E.J.*, Vol. 43, p. 61.

register and translator of the code digits ; but instructions regarding the numerical digits have to be stored somewhere in the switching machine in order to cover the action to be taken, for example, when the numerical digits which have been stored correspond to an unallotted number. In this case, the director sends out stored numerical digits in the same form in which they were received and it is the switches that supply the information, by permanent wiring to N.U. tone on their banks, that the recorded number has not been allotted. It is interesting to note that the operator behaves in practically the same way in these circumstances ; she proceeds to set up the call as if the number were working and finds from the marking on the multiple that the number is unobtainable. This example illustrates the important point that translation even in one system may take more than one form and it is not possible to give a generalised statement of the form of translation for each operation in every system.

In this article only number translators will be considered, that is, register-translator-senders which take in a number, translate it to, and send out, another number. It is difficult to see how some such apparatus can be avoided in any new system for reasons which are given in the next section, which also indicates the scale of the register-translator problem.

National Automatic System With National Numbering.

Many years must inevitably elapse before any new system could be installed in this country in any appreciable quantity, and many years of service would be expected from such equipment. It must, therefore, follow that any new system must be capable of satisfying the needs of a national telephone network for several future decades. These needs may not at this moment be known in detail but, to be sure that future development will not be handicapped, any new system must be capable of giving automatic service on a national basis, that is, it must at least be capable of subscriber-to-subscriber national dialling, with the cost of the calls determined at the time the calls are made.

In this country there are about 6,000 exchanges and the problem of connection between these exchanges by subscriber-controlled signals is clearly of a much larger order than that of the director which is limited to a maximum of 100 exchanges but, in practice, is rarely concerned with more than 30 exchanges. The problem is further complicated by the fact that, in order to identify the 6,000 exchanges, 5-digit exchange codes will probably be necessary. Since a machine exchange must have an instruction built into it for every possible circumstance, it appears that it must be capable of recognising 100,000 numbers. This problem occurs, of course, with the present type of exchanges, and means of reducing the amount of recognition to a much smaller number of items have already been devised. The general principle adopted is that of the allocation of exchange codes according to some system by which whole blocks of exchange numbers can be recognised, each by a single number.

One general principle of numbering is that the whole network is divided into large areas, the exchanges within each of which have codes all beginning with the same first digit, different areas having different first digits. Each large area is then further sub-divided into areas within which the exchanges bear codes having the same first and second digits. Further subdivision of the areas may be necessary, depending on the size of the network but, in the final areas, the exchanges are allocated different digits for the final digits of their codes. For a variety of reasons, only a small number of the available numbers are taken up as working exchange codes ; as already mentioned, in this country 5-digit exchange codes will probably be needed for 6,000 working exchanges. It will be apparent, however, that starting from any point in the system the route to be taken and the charge for the longest-distance calls will be defined by the first code digit. Similarly, some not so distant calls will be defined by two digits and so on, and only in the shortest distance calls will 5-digit codes have to be recognised in full. In this way, the number of numbers which must be individually recognised may be reduced for a country of this size to perhaps 1,000. This is a great reduction, but it still means the recognition of 1,000 numbers having from 1 to 5 digits and the provision of a large number of translations. It is possible to arrange the switching systems so that 5-figure codes are translated in two stages, but however the problem is solved, it is economically difficult to avoid the recognition of at least several hundred numbers having from 1 to 3 digits, and the provision of a corresponding number of translations.

Electronic Registers

It is well known from current practice that numbers may be transmitted, received and registered by a variety of methods and these methods can be reproduced electronically. In one method, exemplified by dialling, a train of impulses is sent for each digit of the number, the number of impulses in each train being equal to the value of the digit which it represents. In another method, each decimal digit is coded into a binary number, the digits of which are sent simultaneously, e.g., multiple frequency key impulsing. In a further method, exemplified by teleprinter code, each decimal number is coded into a binary number, the digits of which are sent in time sequence. Reception is a question of recognising the incoming signals and converting them into a form suitable for the registering equipment. The registers may be, for example, switches with 10 positions into one of which each switch may be set to indicate a number directly ; or, again, four relays operated according to the binary code of the number represented. Some electronic versions of familiar registers will now be described together with some registers which are peculiar to electronic technique.

Dialled Impulse Register.

Fig. 1 shows a register suitable for storing dialled impulse trains which are assumed to consist of positive-going impulses of about 40V amplitude from a low impedance source R1. The cold-cathode-tube counting chain of valves D1, D2...forms a distributor which distributes the trains one each to a counting chain, one

counting chain being indicated by the cold-cathode tubes N1, N2....

The cold-cathode tubes each have an anode, a cathode and a primer. When the primer potential is positive with respect to the cathode by a critical amount called the striking voltage, it initiates an

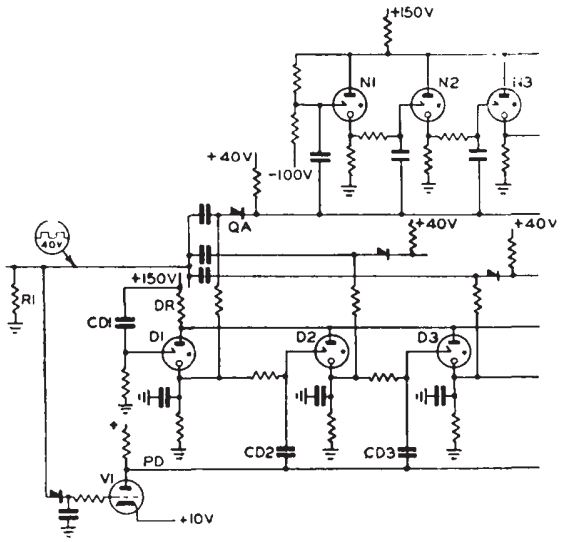


FIG. 1.—A DIALLED IMPULSE REGISTER.

electric current through the gas, which then starts a current between the cathode and anode. The anode current can be stopped only by reducing the anode/cathode voltage below a critical value called the sustaining voltage. In these examples it is assumed that the primer striking voltage and the anode sustaining voltage are both about 70V.

Taking the distributor first, initially the anode voltage is zero, so that no tubes are struck. When the register is taken into service, the anode voltage is applied and this, operating through capacitor CD1, causes the first tube, D1, in the chain to pass anode current. In doing so, it raises the potential of the cathode of D1 by about 40V and thus that of the primer of tube D2 by a similar amount. A positive-going impulse of about 40V applied to the distributor impulse lead PD when added to the cathode potential of tube D1 will cause tube D2 to fire. The capacitors connected between earth and the cathodes of the counting tubes prevent the cathode potentials from changing quickly. When tube D2 fires, therefore, its cathode potential remains momentarily at earth potential, and its anode, therefore, at the sustaining voltage above earth potential. The cathode potential of tube D1 remains momentarily constant, but its potential is reduced by tube D2, and this extinguishes the glow in tube D1. D2 will prime D3, but not until the impulses through the capacitors CD2, CD3 . . . have died away. Further impulses will operate in a similar manner to advance the glow along the chain. The glow is advanced one step for each incoming train of digits by the hot-cathode valve V1, and its circuit. The anode current of valve V1 is normally cut-off. The first impulse of a train of impulses causes the valve to conduct and remain conducting until the impulses stop. This result is produced by the rectifier and capacitor in the grid circuit of the valve. When the impulses stop, the charge across the capacitor leaks away until the valve V1 again cuts off its anode current. In doing so, it applies to the distributor the positive impulse necessary to advance the glow.

Each distributor tube when fired operates a rectifier switch to allow a train of incoming impulses to pass to a counting chain similar to that of the distributor. When tube D1 is fired, for example, the rectifier QA, which is normally biased to its high resistance direction by an amount about equal to the voltage of the incoming impulses, becomes conducting. The incoming impulses are, therefore, communicated to the counting chain which includes tubes N1, N2. . . . The first tube N1 is primed from the anode supply voltage until a tube fires and reduces the tube anode voltage. The first impulse thus operates tube N1, and subsequent impulses operate the tubes in turn as described for the distributor chain.

Coded Impulse Register.

Fig. **2** shows part of an array of gas-discharge tubes

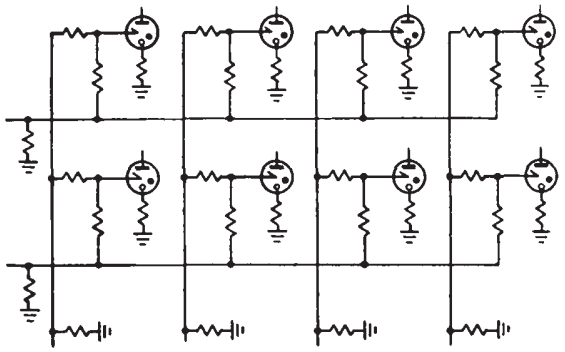


FIG. 2.—A CODED IMPULSE REGISTER.

which is suitable for registering coded impulse numbers. Each row of tubes registers a decimal digit in four-digit binary code. The primer of each tube is connected through two resistors, one to a column common, and the other to a row common. The distributor applies 80V positive to each row common in turn as digits are received. As each digit comes in, a signal receiver applies 80V positive to the column commons according to the value of the digit. As a tube will fire only when its two resistors are at 80V positive, tubes will glow and register the digits which are received. The digits may be received in coded form, for example, by multi-frequency key impulsing, or in any other form and be coded at the receiving point. For example, if the number of dialled trains to be registered is large, it is more economical to code them into binary form before registering than to register them in decimal form, as in Fig. **1**.

Supersonic Delay Line Register.

Supersonic delay line registers have been invented as memory units for automatic computors.[2] Fig. **3**

[2] T. K. Sharpless. "Design of Mercury Delay Lines." *Electronics*, November, 1947, p. 134.

shows one form of delay line. A steel tube is closed at its ends with insulating discs. Let into the inner face of each disc is a metal electrode connected through the disc to an external terminal. Stuck or in some way pressed against each electrode is a quartz crystal.

FIG. 3.—A FORM OF DELAY LINE.

After assembly the tube is filled with methylated spirit or other liquid which wets the surface of the crystal, and the liquid is then displaced by mercury until the whole tube is full of mercury. The crystals are X-cut so that they vibrate in thickness when an alternating voltage is applied across them. A natural frequency of vibration of the crystals of 10 to 15 Mc/s is often used, but the damping by the mercury load and other effects can be made to produce a frequency response which is flat over a bandwidth of several megacycles about the crystal's natural frequency. The mercury is prevented from making contact with the electrodes by making the crystal diameters greater than that of the electrodes. An alternating voltage may be applied to one of the crystals by applying the voltage to the mercury and external electrode terminal. An alternating voltage of suitable frequency applied in this way causes the crystal to vibrate mechanically, and thus to communicate pressure waves to the mercury. The waves travel along the column and in impinging on the crystal at the other end, produce a voltage similar to that at the sending end, but delayed and greatly attenuated. The frequency of the A.C. applied may be about 10 to 12 Mc/s, and the propagation speed of the waves in the mercury is about 1·5 metres per milli-second. If an impulse of, say, 12 Mc/s for one microsecond is transmitted into the delay line, it will come out of the other end the delay time later. If an impulse issuing from the delay line is used to gate a new time-corrected impulse into the delay line, an impulse once started can be made to circulate indefinitely. Impulses may be injected at intervals down to one microsecond, or even less, and all circulated together. In this way capacity for 1,000 impulses has been provided in a delay line about 1·5 metres long. For a telephone exchange register a capacity of about 100 impulses would suffice.

Fig. **4** (*a*) shows the circulation system schematically. A gate G1 has connected to it a pulse source which, because it controls the timing of the circulating system, is called the "clock" pulse. It is common for the impulses of the clock pulse to be 0·2 microsecond long and spaced one microsecond apart. The gate G1 lets a clock impulse through to a second gate, G2, if when the clock impulse occurs, there is a signal on either of the two leads A or B. The gate G2 also has connected to it an A.C. generator, FX of frequency about equal to the natural frequency of the quartz crystals in the delay line. The action of the gate G2 is that when it receives an impulse from the gate G1 it allows the generator current to flow to the delay line input for a fixed time, say one microsecond. An A.C. impulse thus passed into the delay line will emerge after the delay time. After amplification the impulse is passed to the lead B and thence to gate G1, where it will gate a clock pulse to gate G2 and thus start a new impulse

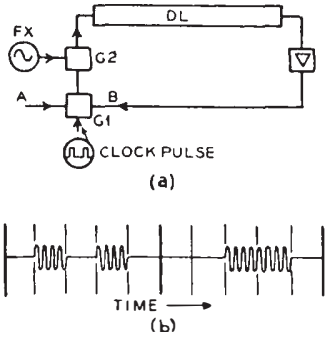


FIG. 4.—SUPERSONIC DELAY LINE REGISTER—(a) SCHEMATIC OF CIRCULATION SYSTEM. (b) PORTION OF CYCLE AS INDICATED BY A CATHODE-RAY TRACE.

into the delay line. Initially there are no circulating impulses, and impulses are registered by an impulse generator which generates them at the right time and passes them into the system over lead A, after which they continually circulate as described.

Fig. **4** (*b*) shows a portion of the cycle as it would appear on a cathode ray tube connected to any part of the circulation system. It shows two 5-binary digit numbers registered, the first with impulses in the second and fourth digit places, the second with impulses in the third and fourth digit places, each impulse being an A.C. impulse at the frequency of the generator FX. These impulses are cyclically repeated at intervals equal to the cycle time of the circulating system which is controlled by the clock impulses. A second clock pulse gives out impulses to mark the beginning of each cycle. The whole of the recorded information appears cyclically as impulses at a single point anywhere in the circulating system, and use can be made of this feature in translating operations. The significance of any impulse is dependent on its time position in the cycle. Registering and "reading" digits is thus a matter of controlling and measuring impulses in time. This needs somewhat complicated apparatus which, however, is independent of the number of impulses in the cycle. Hence the system may be very economical for registering a large number of digits.

Cathode-Ray Tube Register.

Electro-mechanical registers have been made with capacitors as register elements, the charges on the capacitors constituting the record of the numbers received. Fig. **5**, which illustrates this system, shows capacitors in four columns and two rows although many more rows usually are necessary. Each capacitor is shown with a leak resistor which in most cases is the insulation resistance. For each number received capacitors in one row are charged according to a code and constitute a record of the numbers received for so long as the charges on the capacitors persist. The record can be maintained indefinitely by an arrangement which tests each capacitor in turn at frequent intervals and "tops up" the charged ones to

a standard charge. This is a very economical system when the storage required is large.

A cathode-ray tube can be made to operate in roughly the same way even more economically when a very great amount of storage is required.[3] The beam

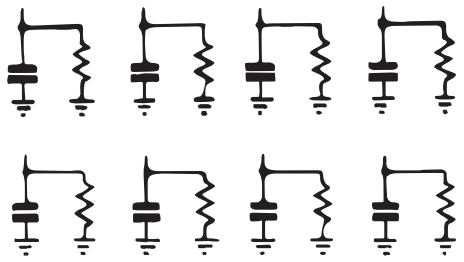


FIG. 5.—CAPACITORS USED AS A REGISTER.

of a cathode-ray tube when suitably controlled can leave the part of the insulating screen on which it impinges charged to one of two potentials. If the beam is caused to travel over the screen in a line, and during the passage over the line the beam is modulated according to the digits of a binary number to be stored, charges representative of the digits can be left on the screen. This is called "writing" on the screen. These charges will soon disappear if no further action is taken. The line is, therefore, scanned at frequent intervals and the charges renewed. Many different numbers are recorded in straight lines parallel to one another and continuously scanned in television picture fashion. In this way a very large amount of number information can be registered and held indefinitely. The amount of common apparatus needed to write the information in the right places, to "read" and to renew the charges is fairly substantial, so that the system shows up to its best advantage when there is a great amount of information to be stored, as there is in the automatic computers for which the system was originally invented. The continuous and cyclic scanning results in the registered information being reproduced, as in delay line registering, in a repeating sequence of timed impulses.

ELECTRONIC TRANSLATORS

The translator function will be approached by way of some practical examples which illustrate three main types of translator.

Static Register-Static Translator.

In Fig. 6, three groups of ten wires each are shown on the left of the figure and represent a three decimal-digit register. Each wire is connected, for example, to the cathode of a register gas discharge tube ; it is normally at earth potential, but when marked by the register takes a positive potential. Any combination of one wire marked in each group can be made to operate a three-electrode gas discharge number tube. The figure shows one such tube operating via rectifiers to the number 142, and marking, through 2 two-electrode gas discharge tubes, one wire in each of two groups of ten wires on the right of the figure. The rectifiers act so that the primer of a tube to which a group of the rectifiers is connected takes up a positive potential only if all the wires to which the group of rectifiers is connected have a positive potential. With this arrangement a large number of such groups of rectifiers are operable with low power consumption from the wire-marking sources. When a tube is fired, its cathode takes a positive potential which causes discharges through the two-electrode marking tubes connected to it, and thus marks a wire in each group, in this example 23. It will thus be seen that number 142 is translated into number 23. It will also be realised that any number of numbers, each of any number of digits, can be translated to other numbers, each of any number of digits, by the provision of sufficient apparatus. The amount of apparatus is clearly considerable even for a relatively simple piece of apparatus like a two-digit director. The natural development to reduce the cost is to make the translator common to a number of registers. The broken line drawn across Fig. 6 shows the division between

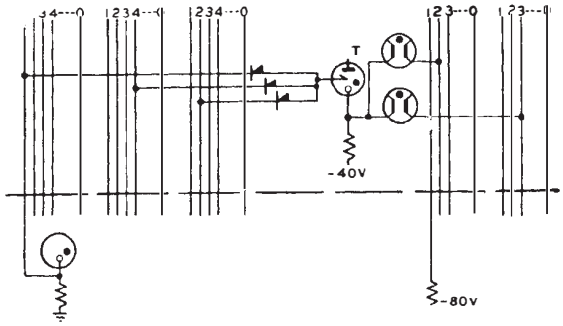


FIG. 6.—THE ELEMENTS OF A STATIC REGISTER-STATIC TRANSLATOR.

the individual register and the common translator. It is obvious that no two registers should be connected simultaneously to the translator. Some means must, therefore, be employed to connect the registers one at a time to the translator. One method is to let each register, when it requires a translation, apply for connection to the translator through a switch which permits only one such connection at a time. The disadvantage of this method is that reference to the translator must be made after a fixed number of incoming digits. This difficulty is surmounted by connecting each register to the common translator after each digit which is received. However, complication still remains in the means for determining that a digit has been received. A further method is to connect each register to the translator in sequence and independently of the incoming digits. By whatever method the translator is made common to the registers, no register should hold the translator for more than the briefest necessary time, which is the time to operate a memory, e.g. a gas discharge tube ; each register then has to have a memory for the translation as well as the incoming digits. For this reason, it is sometimes economical to read the translator digits out of the translator one at a time. This may readily be achieved by adding to the code digits an

[3] F. C. Williams and T. Kilburn. "A Storage System for Use With Binary Digital Computing Machines." *J.I.E.E.*, 96, p. 81 (Part III, March 1949).

extra digit which records the number of translation digits read out. By this method, the translator is made more complicated, but the register less so. In the example given in Fig. **6**, instead of one tube T, operated by the received code and giving all the translation digits, there would be a number of tubes T, each operated by the same received code plus a different digit recording the numbers of translation digits read out, and each providing one translation digit. The number of tubes T required in the common translator is increased from the number of codes requiring translation to the number of codes requiring translation multiplied by the average number of translation digits per code, but the economy in the register may easily offset the extra expense in the common translator.

Static Register-Pulse Translator.

In Fig. **7** (*a*), the lower portion of the figure is

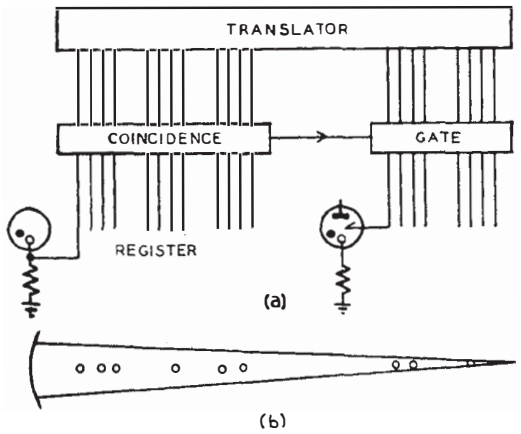


FIG. 7.—THE ELEMENTS OF A STATIC REGISTER-PULSE TRANSLATOR.

concerned with the register and the upper portion with the translator. On the left are three groups of four wires below the apparatus marked "coincidence." These wires are marked according to the binary code, by the register gas discharge tubes. On the right are two groups of four wires ; each wire has one end connected to a gate apparatus and the other terminated on a gas discharge tube which is fired when the wire is marked with a suitable potential. For each wire connecting the register to the coincidence apparatus, there is a corresponding wire joining the coincidence apparatus to the translator, and similarly for the gate apparatus. The translator presents in cyclic order to the coincidence apparatus all the incoming numbers for which a translation is required, each number being presented as markings, in binary code, of the wires to the coincidence apparatus. Thus, in an extreme case, one thousand codes corresponding to all the numbers from 000 to 999 would be presented to the coincidence apparatus. For each number which is thus presented the corresponding translation in coded numbers is at the same time presented to the gate apparatus. When a translator incoming number coincides with the incoming number registered in the register, the coincidence apparatus operates the gate, which is normally "closed," and allows the translation numbers to be passed to the register and there stored. The speed at which electronic apparatus can work makes presentation of a great number of different translations in a short interval of time relatively easy.

The translator is a variable pulse generator which may take various forms. One is indicated in Fig. **7** (*b*), which shows a sector of a disc. Each sector corresponds to one "entry" in the translator, the entry taking the form of holes punched in the disc in positions corresponding to the required wire markings. The disc on being rotated between a light source and an appropriate number of photocells, causes the required pulses to be generated in the photocells. There are other and better methods of generating the pulses, but all are too expensive to be individually provided for each register. There is no difficulty, however, in one translator serving a number of registers. Each register, if connected to the translator through its own coincidence and gate circuits, can operate quite independently of the others, and by adding an extra digit to the code digits, as described for Fig. **6**, the translation digits can be extracted one at a time to save translation registers.

Pulse Register-Pulse Translator.

Fig. **8** shows schematically the further development of the previous register-translator in which both the register and translator operate with pulses. The register may be of the supersonic delay line or cathode-ray tube type, or any type giving the registered information in a cycle of pulses synchronised by a "clock." In Fig. **8**, this is represented by the circle marked "register cycle." The translator has a code cycle similar to, but much longer than, the register cycle, and synchronised by the same "clock." Written into the translator code cycle are all the codes for which translations are needed, these codes being written into the cycle in positions such that the impulses of a code will appear at the output of the cycle at the same time

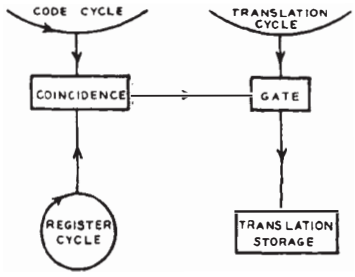


FIG. 8.—THE ELEMENTS OF A PULSE REGISTER-PULSE TRANSLATOR.

as the impulses of the same code written into a register cycle will appear at the output of the register cycle. An impulse code coincidence detecting circuit connecting the outputs of the code and register cycles operates a gate circuit for a given time after detecting coincidence between a registered number and a code cycle number. During the time the gate is operated, the translation in coded impulses is given out from a

translation cycle in the translator, and will pass into the register and be stored there.

With this method the coincidence and gate circuits can be very simple. The registered numbers must be in pulse form, which in practice limits the method to delay line and cathode-ray tube registers. The code and translation cycles in the translator have to be very long, many thousand of pulses in some cases; this requires a high-speed technique with impulses of the order of one microsecond in length. In general, the method shows up to best advantage when the number of translations is very large.

Electronic Senders

Registering a number consists of detecting or receiving the number, converting it if it is not already in a form suitable for registering, and finally registering the number. Sending is the reverse process. Given a registered number, this has to be converted, if not already suitable, into a form suitable for transmitting, and finally transmitted in the required form.

The number of forms that sending may take is very large, being equal to the number of combinations of ways in which numbers may be registered with the ways in which numbers may be transmitted. Nevertheless, the sending problem is a relatively simple one and a single illustration will suffice to show the type of operation involved. In general, numbers are transmitted either by a train of impulses or by binary code impulses. In the following example, registered decimal numbers are sent out in two-out-of-five binary code.

Fig. **9** shows the elements of a sender designed to

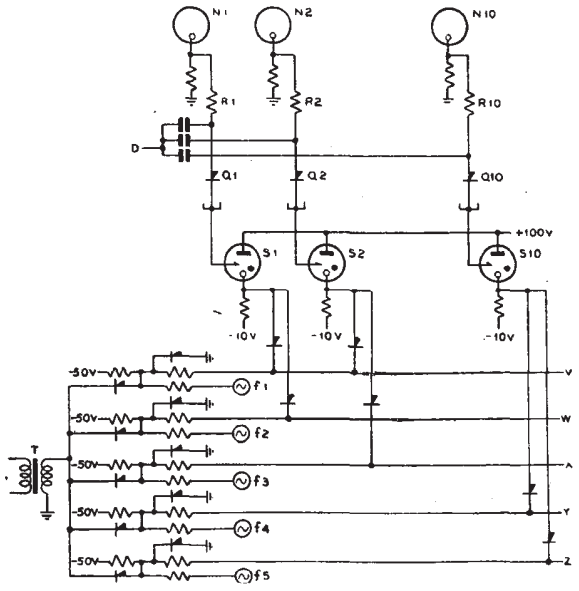


Fig. 9.—The Elements of a Sender.

read out from decimal static registers, convert to combinations of two-out-of-five frequencies and transmit the frequencies to a transmission channel. This is a common arrangement for sending from one register to another over a junction or trunk circuit. One decimal register is represented by the row of cold-cathode gas tubes N1, N2 . . . N10. These may, for example, be tubes N1, N2 . . . in Fig. **1**, with the addition of the circuit elements about to be described. The cathode of each tube N is connected through a resistor R and rectifier Q to the primer of a gas discharge tube S; the junction between each resistor R and rectifier Q is connected through a capacitor to a lead D. There will be a number of decimal registers each as shown in the diagram, and commoned to the primers of the tubes, S.

The lower portion of Fig. **9** shows the frequency-sending arrangements. The five frequencies are produced by the generators f_1, f_2 . . . f_5, and these are connected through rectifier switches to the output transformer T. Normally the rectifier switches produce high attenuation between the generators and the output, but any wire V, W, X, Y or Z, the potential of which is raised substantially above earth potential, will bias its associated rectifier switch into the low attenuation condition and thus send one of the frequencies. The conversion from decimal to two-out-of-five code is performed by the rectifiers which connect the cathodes of the valves S to the wires V, W, X, Y, Z.

Before sending commences, one tube in each decimal register will be glowing, but none of the tubes S will be struck. When sending is to commence, a positive-going impulse will be applied to the lead D of the first decimal register. This impulse will raise the potential of the primers of all the tubes S, but one primer, the one connected to the glowing valve N, will be raised more than the others and its tube will be the only one to glow. The potential of the cathode of this tube will become positive with respect to earth, and the current through the two rectifiers connected to the cathode will cause two of the five frequencies to be transmitted. To terminate the sending, the anode voltage of all the S tubes is reduced so that the one tube struck ceases to conduct. To send the next digit, an impulse is applied to the D lead of the second decimal register tubes N, and the process described is then repeated.

Conclusion

It is hoped that the description and examples given will convey the future scope of the register-translator problem and some of the possibilities of all-electronic solutions to the problem. It will be appreciated, of course, that the register-translators described do not apply only to fully electronic exchanges. Partially or fully electronic register-translators, or register-senders without translation, may very likely find their way into existing systems. For a possible all-electronic automatic exchange system, however, the existence of an all-electronic register-translator-sender means that the speech path switches can be connected and controlled according to any of the well-known trunking and selecting systems, which will form the subject of the next article.

A Drawing Office Aid in Isometric Projection

R. H. CHAPMAN, B.Sc., A.M.I.E.E., and E. C. SHIPLEY†

U.D.C. 515.69 : 621.71 : 744

The article describes a novel machine which enables views in isometric projection to be easily traced from conventional orthographic engineering drawings. Some examples are given of its application to P.O. Engineering Department work.

Introduction.

THE majority of Departmental Technicians are electrical rather than mechanical specialists; moreover, as they are, generally, more concerned with maintenance than with the manufacture of mechanical or electro-mechanical equipment, they do not normally have the opportunity of becoming so familiar with reading and interpreting conventional mechanical drawings as do their colleagues in workshop or drawing office. In preparing instructions for installation and maintenance, particularly when dealing with detailed mechanical features, there is, therefore, a considerable demand for semi-pictorial views of items, but the production of drawings of this type has been restricted owing to the high cost in drawing-office man hours.

For these reasons, a drafting machine, known as the Parallel Perspector and constructed on pantographic principles, has been obtained from Isometric Projections, Ltd., Bucks., which enables isometric views to be traced readily from conventional orthographic drawings. Experience with the machine has shown that a reasonably experienced operator can produce a complicated isometric view in a fraction of the time taken by normal drafting methods. It is hoped that the acquisition of this machine will enable the usefulness of the semi-pictorial nature of isometric views to be more widely exploited by the Department than has been possible in the past.

Principles of Isometric Projection.

To enable the functioning of the machine to be better understood it may be desirable to reconsider some of the principles of isometric projection. An isometric view is a plane view in which the three rectangular dimensions (length, breadth, and height) are drawn parallel, respectively, to three main axes which are equiangularly spaced, the one axis being vertical and the other two making angles of 120° with it. The object is viewed from such an angle that the item is symmetrically disposed and the apparent lengths of dimensions parallel to the three main axes are equally foreshortened.

A cube of unit side is represented isometrically by Fig. 1. BD is evidently a true length ($=\sqrt{2}$), from which it follows that side AB $= \sqrt{2}/2 \cos 30° = 0{\cdot}816$.

If Fig. 2 represents an orthographic elevation and plan of the cube, and α is the angle of vision from which the cube is viewed to obtain the isometric projection on a plane at right angles to the line of vision, the apparent length of AE (i.e. length AF in Fig. 1) is AH (= 0·816), therefore, cos α = 0·816 and $\alpha = 35° 16'$.

A circle tangential to each of the four sides of any face of the cube has a diameter of unity and, in the isometric view, becomes an ellipse whose major axis is also unity and whose minor axis is sin 35° 16′ (i.e. 0·577).

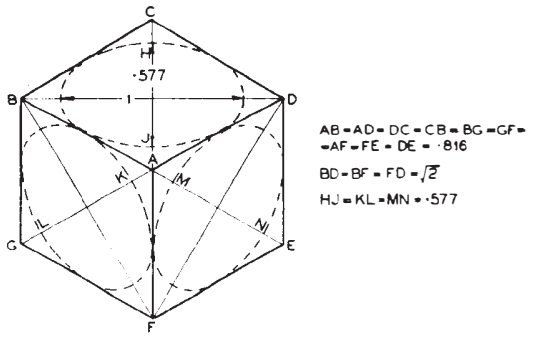


FIG. 1.—PRINCIPAL DIMENSIONS ON ISOMETRIC VIEW OF CUBE OF UNIT SIDE.

Basic Principles of the Perspector.

From the foregoing the two main requirements for an isometric drafting machine are therefore:—

(1) A means of producing from a circle an ellipse

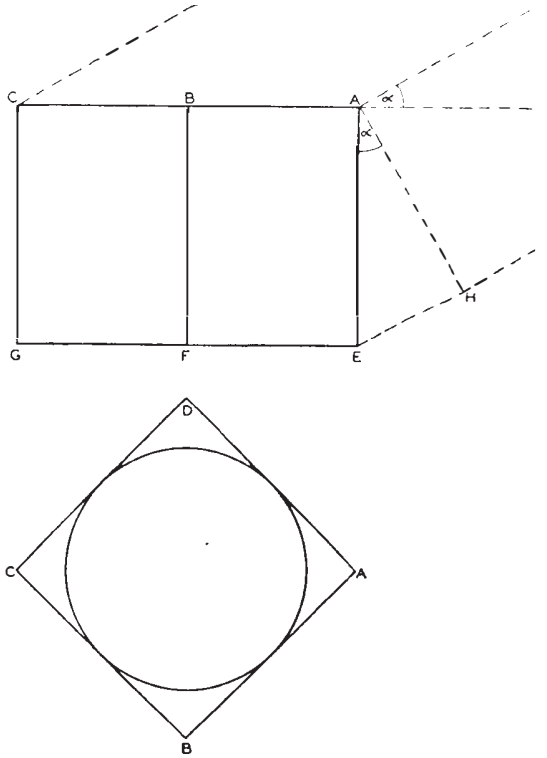


FIG. 2.—ORTHOGRAPHIC ELEVATION AND PLAN OF CUBE, SHOWING ANGLE OF SIGHT FOR ISOMETRIC VIEW.

† The authors are, respectively, Assistant Staff Engineer and Senior Draughtsman, Subscriber's Apparatus and Miscellaneous Services Branch, Engineer-in-Chief's Office.

in its appropriate position with an axis ratio of 0·577 to 1.

(2) A method of setting off the various lengths in an orthographic drawing to a scale of 0·816 to 1 on the isometric drawing.

For the perspector, the first requirement is met by means of a double pantograph mechanism, enabling an ellipse of the correct size and location to be drawn by tracing over the equivalent circle on the orthographic master drawing. The second requirement is met by moving the isometric drawing board crosswise in relation to the board carrying the orthographic drawing, the movement being made according to any particular scale selected by the operator as being appropriate to the drawing being dealt with.

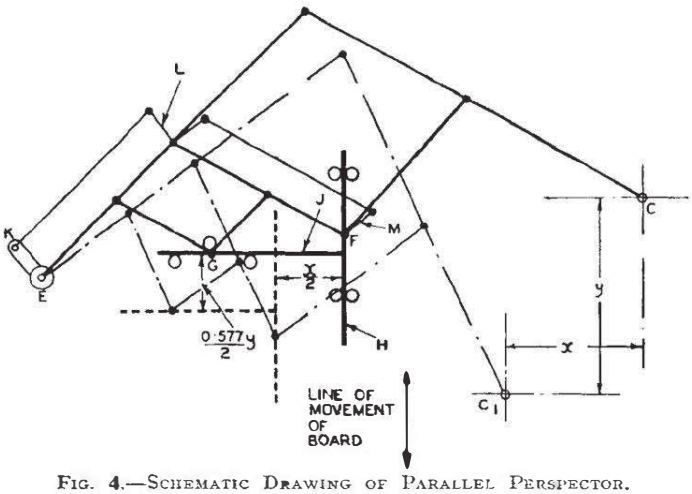


FIG. 4.—SCHEMATIC DRAWING OF PARALLEL PERSPECTOR.

Outline of Constructional Features and Principles of Operation.

Fig. 3 shows a general view of the machine, while Fig. 4 gives the skeleton schematic equivalent. The orthographic master drawing is affixed to board A (Fig. 3) and the isometric view is produced to half normal isometric scale on paper pinned on board B (Fig. 3) which is movable transversely relative to board A. C is the orthographic tracing point, D the isometric drawing point, and E the main pantograph linkage pivot. F and G are further pantograph linkage pivots, F giving a 1 : 2 reduction of the motion of C, and G giving a 0·577 : 1 reduction of motion of F, i.e. 0·577/2 : 1 reduction of the motion of C. The pantograph link arrangement is such that the points C, F, G, and E always lie on a straight line.

Referring to Figs. 3 and 4, the pencil D is carried on a spider, to the underside of which are fixed hardened and ground steel straight-edges H and J forming a ⊥ shaped member. Straight-edge H slides between two pairs of guide rollers on a carriage integral with the pivot pin at F, whereas J is similarly constrained by three rollers on a carriage integral with pivot pin G. The ⊥ member is maintained always parallel/normal to the line of motion of the left-hand board (Fig. 3) by a subsidiary linkage KLM, coupling the 4-roller guide carriage to a fixed point K on the main pivot bearing housing.

Referring to Fig. 4 it will be evident that if C is moved to C_1 (i.e., a distance y parallel to the direction of motion of the left-hand board and x at right angles to it) the ⊥ member and tracing pencil D move $0{\cdot}577y/2$ and $x/2$, respectively, parallel to these two directions.

The motion of the left-hand board is separately controlled by hand wheel R (Fig. 3), the system of transmission consisting of steel wire stretched over guide pulleys, giving smooth and easy movement without backlash.

The machine is precision finished and all pivots are fitted with ball bearings. By means of a bowden wire control, operated from the tracing point C, the pencil at D can be made operative or non-operative at will.

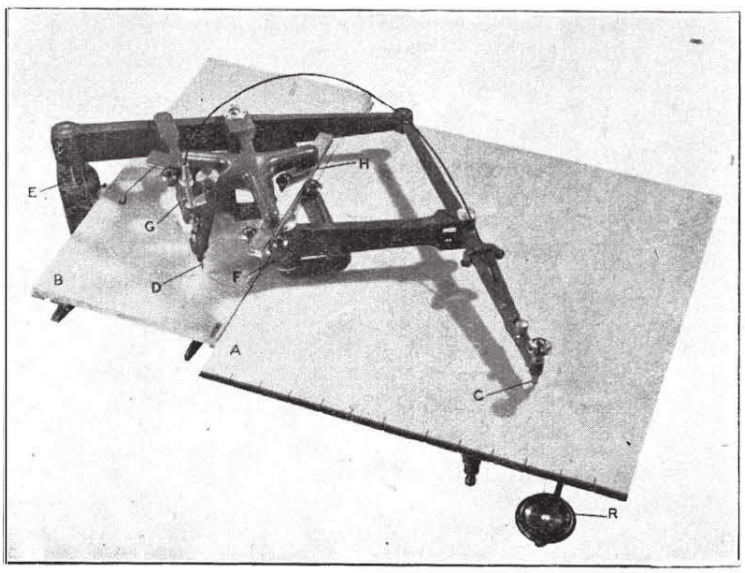


FIG. 3.—GENERAL VIEW OF THE PARALLEL PERSPECTOR.

Making a Drawing.

Referring to Fig. 5, in which a simple example is taken to demonstrate the principle, the orthographic plan and elevation drawing is pinned to the fixed board of the perspector so that the axis of the drawing is at an angle of 45° with the edge of the board. The points ABCDEF where abrupt changes in level occur in the orthographic elevation, are marked off and reproduced along the edge of the fixed board, the distances between the points being scaled down to 0·816/2 of the original value. (A standard conversion chart is issued to facilitate this.)

With the movable board located so

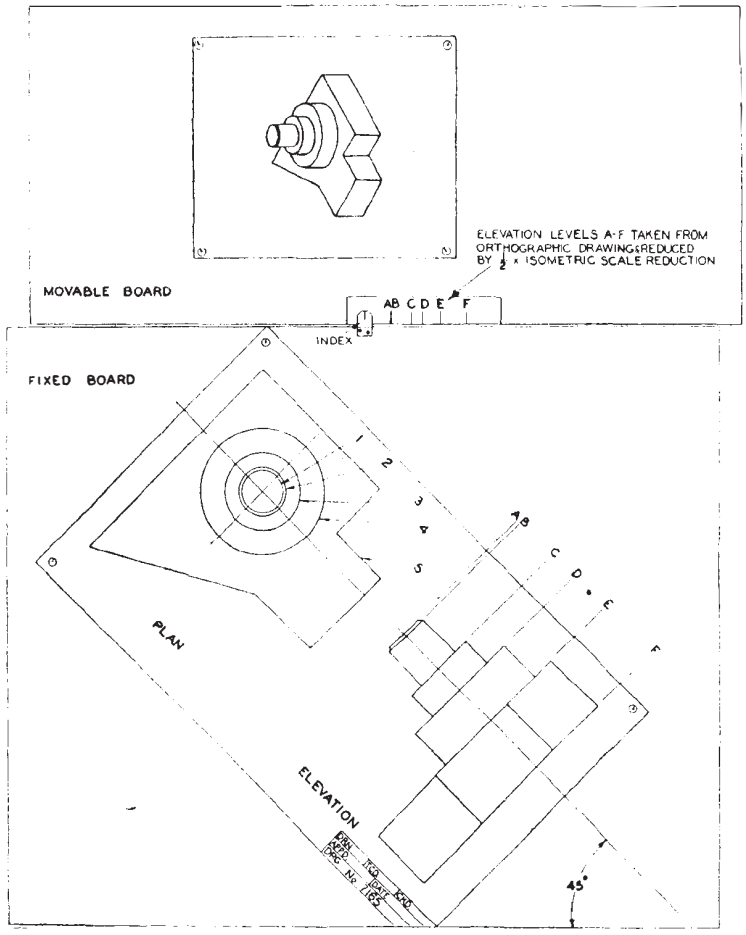


FIG. 5.—SIMPLE EXAMPLE OF THE METHOD OF CONSTRUCTION.

that the index pointer covers A on the scale, an ellipse is traced by tracing over plan circle 1 (the small ellipse at the extreme left of the isometric view). The movable board is then shifted so that the pointer covers point B on the scale and as much as is required is traced from plan circle 2. The movable board is then shifted on to point C and a semi-ellipse is reproduced by again tracing over half of plan circle 2.

With the tracing point held stationary at one extreme of the latter half circle and with the tracing pencil depressed, the movable board is retracted back to B. This motion is repeated with the tracing point held stationary at the other extreme of the half circle. These two operations draw in the two horizontal lines outlining the small diameter pin, or shaft, in the isometric view. The reproduction of the two other portions of wider diameter is carried out similarly.

The movable board is then shifted so that the index pointer registers with point E and, with the pencil depressed, the tracing point is run over as much of the main outline (5) of the plan as is required. This operation is repeated after shifting the movable board to point F. The corresponding corner points are then joined by straight lines and the isometric view is thus completed.

To facilitate tracing, the machine is supplied with a number of drawing aids and accessories for the operator, e.g. radius arms for tracing circles, set squares suitably grooved for tracing straight lines and also grooved for tracing circles of small diameter. All tracing from the orthographic drawing is made by fitting a suitable groove over the desired line and drawing the orthographic tracing point along it.

Exploded Views.

An example of an exploded view produced with the aid of the perspector is given in Fig. 6. The exploded view drawing is particularly useful for showing, not only the detailed piece-part make up of a complex item, but also the order of assembly. This type of view is also an instance where the facility of the separate control of the traverse of the movable board is used—in this case, to space out the separate piece parts to the distance required.

Conclusion.

The results obtained from the use of the machine have so far been encouraging, savings of as much as 85 per cent. in drafting time having been obtained in particular instances; also, no doubt with further experience, new applications will be found for the machine.

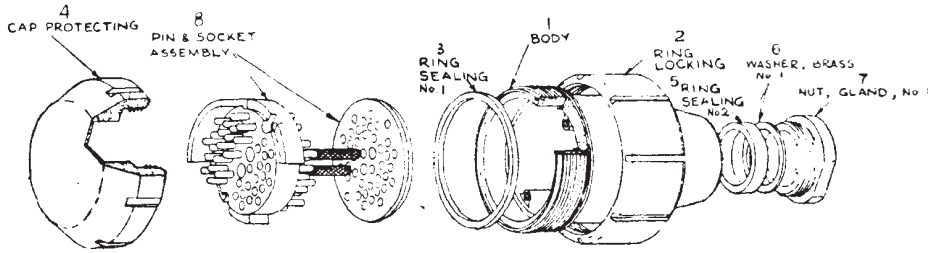


FIG. 6.—EXPLODED VIEW OF A CABLE CONNECTOR PRODUCED ON THE PARALLEL PERSPECTOR.

Finally, the authors wish to extend their thanks to Isometric Projections, Ltd., for supplying the photograph used for Fig. 3.

A Survey of Modern Radio Valves

W. J. BRAY, M.Sc.(Eng.), A.C.G.I., D.I.C.†

Part 6(b).—Valves for Use at Frequencies Above 3,000 Mc/s

U.D.C. 621.385 : 621.396.615.14

In this concluding part of the series*, the principles of operation, methods of construction and characteristics of low-power oscillator and amplifier valves suitable for use in radio and wave-guide relay systems operating at frequencies above 3,000 Mc/s are described. The valves referred to include klystron amplifiers, travelling-wave and electron-wave amplifiers, grounded-grid triode amplifiers, klystron oscillators and continuous-wave magnetrons. The suitability of the oscillators for amplitude, frequency or pulse modulation is discussed.

(Continued from previous issue)

Oscillators

Double-resonator Klystron Oscillator.

If the buncher and catcher resonators of a double-resonator klystron amplifier are coupled by a feed-back path as shown in Fig. **8**, oscillation will occur if the phase-shift round the complete loop is an integral multiple of 2π radians and the small-signal

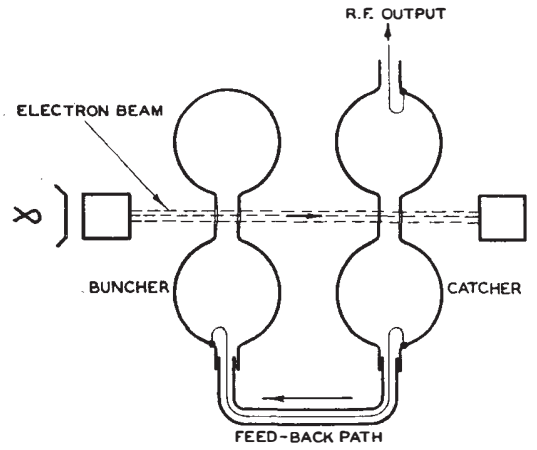


Fig. 8.—Simplified Sketch of Double-Resonator Klystron Oscillator.

gain through the valve exceeds the loss in the feed-back path. The resonators and the feed-back loop behave as a pair of coupled tuned circuits and the frequency of oscillation adjusts itself until the required phase conditions are satisfied. If the beam voltage is varied the transit time of the electrons and therefore the phase-shift in the drift space also vary, and the frequency changes to a new value such that the total phase shift is once again an integral multiple of 2π. If the resonators are under-coupled the frequency of oscillation varies as an approximately linear function of the beam voltage over a limited range; this characteristic may be used for automatic frequency control or for frequency-modulation but with the disadvantage, as compared with the reflex klystron referred to below, that appreciable modulating power is required, and the linear range of frequency control is usually limited to a few megacycles per second. There is the additional disadvantage that both resonators must be adjusted if the mean frequency is to be shifted manually, as compared with the one adjustment needed in a reflex klystron.

Reflex (single-resonator) Klystron Oscillator.

For many purposes the single-resonator reflex (or reflection) klystron oscillator[18, 19] is preferred to the double-resonator klystron because of the ease of tuning and simplicity of construction. In a reflex klystron oscillator the electron beam traverses the resonator gap twice, first in a forward direction from the cathode, after which the beam is returned from a reflector electrode held at a negative potential with respect to the cathode and crosses the gap again in the reverse direction. The beam becomes velocity modulated in the first transit and subsequently develops bunches in the retarding field region around the reflector electrode. The drift time is determined by the anode; i.e. the resonator, voltage, and by the reflector voltage relative to the cathode since the former determines the electron velocities and the latter the distance they travel in the drift space. By suitable adjustment of these voltages the drift time can be made such that each bunch arrives in the correct phase to give up energy to the resonator, a condition which is fulfilled if the drift time is $n + \frac{3}{4}$ periods of the oscillation, n being an integer usually in the range 2 to 10. Oscillation occurs if the energy extracted from the beam is equal to, or exceeds, the losses in the resonator and the load circuit.

Since the frequency of oscillation can be varied over a limited range by adjustment of the reflector-cathode voltage and the reflector current is negligible, the reflex klystron is particularly useful as an electronically-tuned beating oscillator in a receiver, or as a low-power frequency-modulated source for a transmitter.

The VX5026 valve is a typical low-power reflex klystron oscillator developed in the Research Laboratories of Electric and Musical Industries, Ltd., for use in the frequency range 3,900 to 4,200 Mc/s. The valve is shown in section in Fig. **9** and its general

† Assistant Staff Engineer, Radio Experimental and Development Branch, E.-in-C.'s Office.

* Because of a dispute in the printing trade it was necessary to split Part 6 of this series at a late stage. Part 6(a) in the previous issue introduces the subject and deals with Amplifier valves.

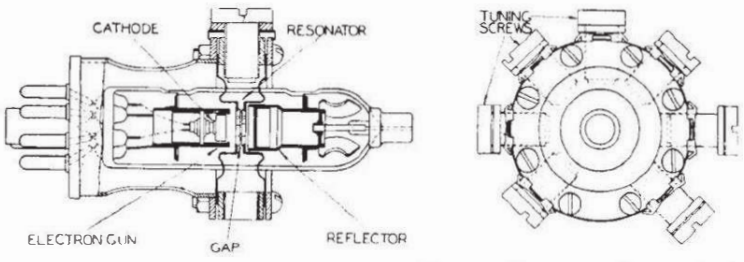


FIG. 9.—SECTION OF SINGLE-RESONATOR REFLEX KLYSTRON OSCILLATOR.

appearance can be seen from the photograph, Fig. 10. Typical operating conditions are set out below.

Anode (resonator)-cathode voltage	+ 250 V
Reflector-cathode voltage	0 to −200 V (depending on mode of operation)
Cathode current	27 mA
Maximum R.F. power output	160 mW
Efficiency	2·4%

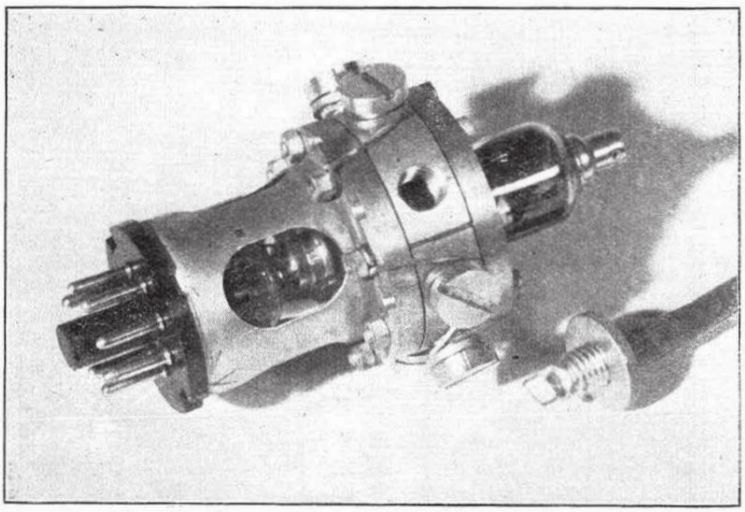


FIG. 10.—REFLEX KLYSTRON OSCILLATOR, VX 5026.

The variation of frequency with reflector-cathode voltage is shown in Fig. 11, together with the corresponding variation of R.F. power output. Two different modes of operation are shown, corresponding to different values of the integer n mentioned above. It is evident that a nearly linear variation of frequency of some ± 5 Mc/s for ± 5 V variation of the reflector-cathode voltage can be achieved with little variation of output; the loading of the valve must, however, be adjusted to a suitable value if optimum linearity is to be obtained. Measurements of the modulating voltage required at various frequencies for constant frequency deviation show that modulating frequencies up to at least 10 Mc/s can be accommodated with a variation of response not exceeding 1 db.

Coaxial-line Oscillator.

The coaxial-line type of valve[5] was developed in the Research Laboratories of Standard Telephones & Cables, Ltd., as an oscillator for use in low-power transmitters or as a beating oscillator in superheterodyne receivers.

The valve consists essentially of a short length of coaxial line, short circuited at one end and open at the other, as in the CV230 valve shown in Fig. 12. The tubular inner conductor is capacitively coupled at one end to a short antenna for feeding an external circuit such as a resonant cavity or wave-guide. The coaxial line is slotted at about one-quarter wavelength from the closed end to permit an electron beam to pass through it, thus forming two gaps (*a*) and (*b*) analogous to the buncher and catcher gaps of a two-resonator klystron. The electron beam is formed by a cathode and control grid together with a screen grid acting as a primary accelerator, and is collected on an anode on the side of the coaxial line opposite to the gun assembly. A magnetic field of at least 1,000 oersteds is necessary to prevent spreading of the electron beam, the field being provided by a permanent magnet.

The coaxial line oscillator operates in a somewhat similar manner to the double-resonator klystron oscillator; the first gap (*a*) produces velocity modulation and hence bunching in the "drift-space" formed by the inner conductor, and the second gap (*b*) functions as a catcher gap. The electric fields across the two gaps are equal in magnitude and differ in phase by 180°, since the buncher and catcher resonators are in fact a single resonator or may be regarded as two resonators with unity coupling. The operating frequency is adjusted manually by tuning the wave-guide cavity but the beam accelerating voltage, which is applied between the coaxial line and the cathode, must also be varied according to the operating frequency, since the accelerating voltage controls the drift-time and, therefore, the phase of the electron bunches relative to the R.F. field across the second gap.

Typical characteristics for the CV230 valve are given below.

Frequency range	2,960-3,000 Mc/s
Resonator-cathode voltage	+ 265 V
Anode-cathode voltage	+ 275 V
Anode current	33 mA
Cathode current	60 mA
Electronic tuning range (for 3 db. decrease of R.F. power)	20 Mc/s
R.F. power output	350 mW
Efficiency	2%

Similar valves have been designed for use in the frequency range 3,600 to 4,200 Mc/s and these valves are suitable for linear frequency modulation with a deviation of up to ± 5 Mc/s.

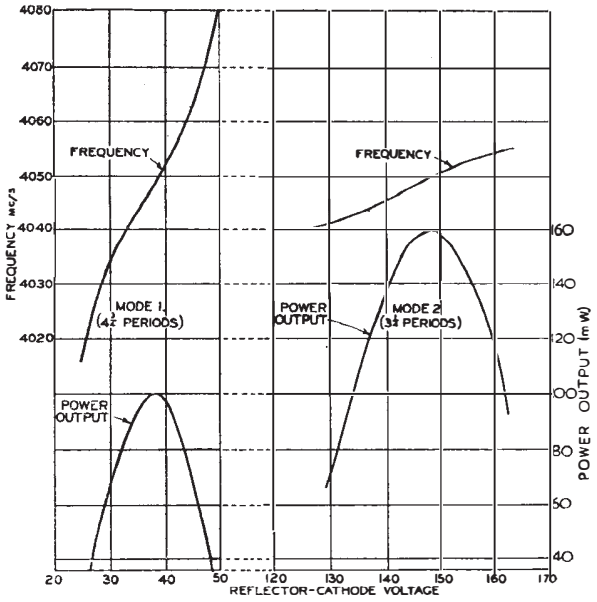


FIG. 11.—VARIATION OF R.F. POWER OUTPUT AND FREQUENCY WITH REFLECTOR-CATHODE VOLTAGE FOR REFLEX KLYSTRON OSCILLATOR, VX 5026.

Magnetron Oscillator.

Magnetron oscillators are of interest because of their high efficiency compared with other sources of centimetre waves and their ability to deliver very large R.F. peak-power outputs. The latter feature, although of great importance in radar, is of less interest for communication systems since the transmitted power required in such systems is relatively small.

The main feature of the magnetron oscillator[20] for centimetre waves is the use of an anode block consisting of a ring of resonant cavities or slots, as shown in Fig. **13** (*a*). An oxide-coated cathode is arranged axially in the centre of the anode block,

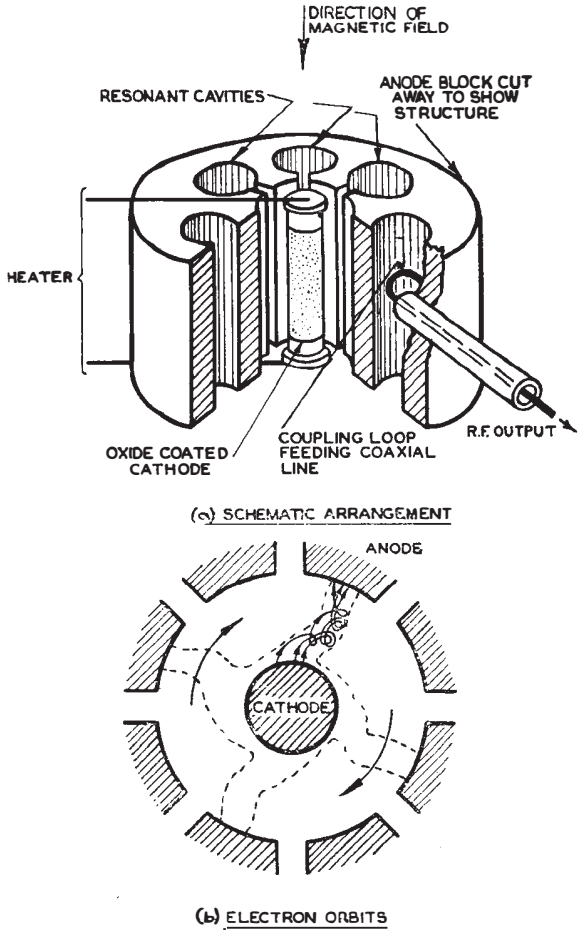


FIG. 13.—MAGNETRON OSCILLATOR.

the whole being enclosed in a sealed-off metal or glass envelope forming a vacuum enclosure. An axial magnetic field is provided from an external permanent magnet or an electro-magnet. A large direct voltage

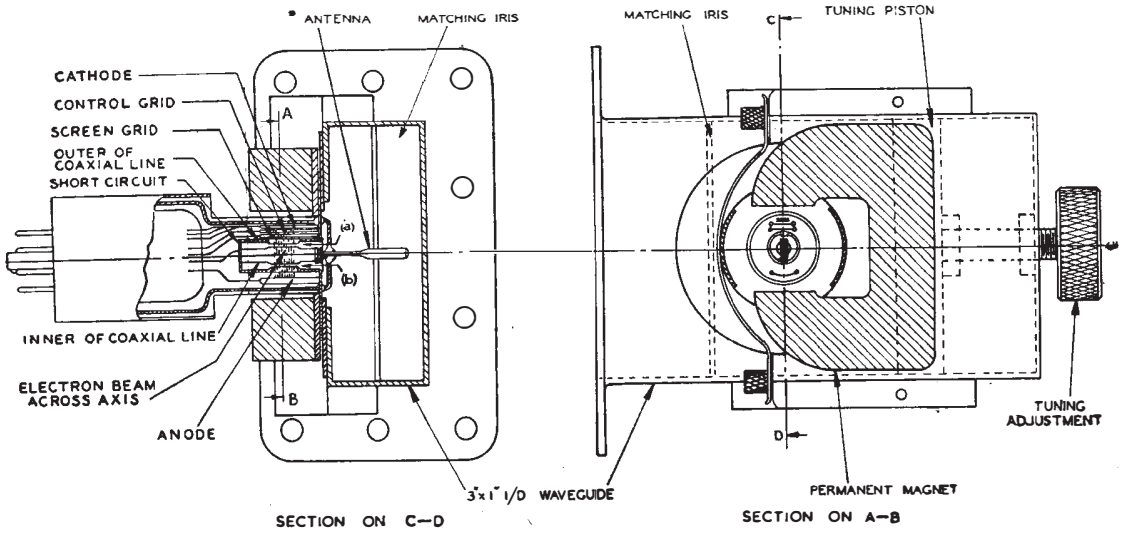


FIG. 12.—SECTION OF COAXIAL LINE OSCILLATOR, CV 230, OPERATING INTO WAVEGUIDE.

is applied to the anode block with the result that electrons flow from the cathode to the anode. In the normal mode of operation the electric fields across the gaps of the cavities differ by 180° or π radians at adjacent gaps—this is known as the "π mode". Other modes of oscillation can exist, and since they may cause frequency instability, arrangements are often made to inhibit such unwanted modes by strapping together the segments that should oscillate in phase; alternatively, the dimensions of alternate cavities or slots may be so proportioned that the frequencies of unwanted modes are well removed from that of the wanted mode—this is known as the "Rising Sun" technique from the appearance of the modified anode block.

The simultaneous action of the constant axial magnetic field and the oscillatory electric field due to the resonant cavities causes the electrons to follow complex paths, as indicated, for example, in Fig. **13** (*b*). Some electrons are returned to the cathode and give up their energy as heat, but the majority of the electrons travel towards the anode and transfer their energy to the oscillating system of cavities. The electrons moving across to the anode tend, by the combined action of the direct magnetic field and the R.F. electric field of the oscillating system of cavities, to be concentrated in radial spokes of space-charge within the limits shown by the dotted lines in Fig. **13** (*b*). These radial spokes of space-charge rotate in synchronism with the R.F. electric field and maintain the state of oscillation by giving up energy to the field. R.F. power can be abstracted from a magnetron by means of a small loop coupling with the R.F. magnetic field within one of the cavities, or by a probe coupling with the R.F. electric field.

Amplitude modulation characteristics.—The oscillating magnetron is not very suitable for amplitude modulation, e.g. by varying the anode voltage, since the relation between the R.F. output and anode voltage is generally non-linear and appreciable unwanted frequency modulation usually occurs.

An arrangement in which a non-oscillating magnetron is used to amplitude-modulate a R.F. carrier flowing along a wave-guide has been described by Gutton and Ortusi.[21] In this arrangement the impedance presented by the magnetron to a coaxial cable is varied by varying the anode voltage; the impedance variations in the coaxial cable are transferred to a wave-guide and thus modulate the amplitude of a wave flowing along the guide. A 100 W carrier at 1,500 Mc/s was linearly modulated up to 80 per cent. at frequencies up to 10 Mc/s, the R.F. power loss in the magnetron being only 1 W.

Frequency modulation characteristics.—The Radio Corporation of America has produced a C.W. magnetron[22] suitable for frequency modulation, the mean operating frequency being 4,000 Mc/s. The valve has 12 vane-type cavities through one or more of which an auxiliary electron beam is passed (Fig. **14**), so introducing an admittance across the cavity, the magnitude of which depends on the amplitude of the beam current. Thus, if the beam current is varied by a control grid, the frequency of oscillation can be varied over a limited range. The

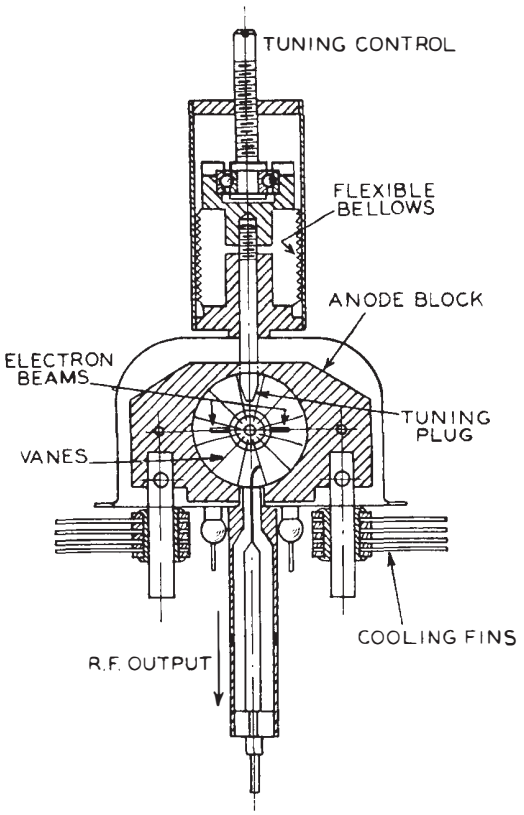


FIG. **14**.—CW MAGNETRON, ARRANGED FOR FREQUENCY MODULATION BY ELECTRON BEAMS.

characteristics of a typical valve are given below:

Operating frequency	4,000 Mc/s
R.F. output	25 W
Efficiency	50%
Anode-cathode voltage	850 V
Anode current	60 mA
Frequency deviation (with two electron beams)	± 2·5 Mc/s

Pulse modulation characteristics.—An example of a low-power pulse-modulated C.W. magnetron for a multi-channel telephony radio link is that used in the Wireless Set No. 10,[23] developed by the Signal Research and Development Establishment during the war. Magnetrons CV79 and 89 used in this equipment produce R.F. power outputs of 300 mW at 4,550 and 4,750 Mc/s respectively. The magnetron is inserted with the anode axis across the shorter dimension of a wave-guide and an $H_{0,1}$ wave is launched into the guide by direct radiation from the anode. Pulse modulation is produced by changing the anode voltage from 450 V (non-oscillating) to 600 V (oscillating), the intelligence being transmitted by variation of the pulse length.

Conclusion.

It is evident from this account that many of the valves for use at frequencies above 3,000 Mc/s are in the early stages of development and that new techniques may be expected to appear in the next few years. Considerable attention has been paid to

achieving the required performance characteristics in terms of gain, power output and noise factor, but it is clear that valve life, stability of performance and cost of production will need greater attention in the future. Nevertheless, a number of valves for use at frequencies around 4,000 Mc/s are now reaching the stage where their use in radio relay systems for commercial operation can be envisaged. Valves will probably be required in the future for radio relay systems operating at frequencies in the range 5,000 to 7,000 Mc/s, and it is likely that techniques similar to those used at 4,000 Mc/s can be employed in this frequency range. Valves for use in wave-guide relay systems above 30,000 Mc/s will probably require appreciably different techniques; however, there is now experimental evidence that both oscillator and amplifier valves for such frequencies can be made.

Several of the valves described for use in communication systems were originally designed for use in radar systems and it is clearly desirable to co-ordinate valve development in these two fields; this is ensured by the Co-ordination of Valve Development Committee (Admiralty) which is responsible for the development of valves both for the Services and for certain civil applications.

Acknowledgments.

The author is indebted to Standard Telephones & Cables, Ltd., Electric & Musical Industries, Ltd., the Admiralty Signal and Radar Establishment and the Services Electronic Research Laboratory for supplying data and samples of the valves described. The permission of the Co-ordination of Valve Development Committee (Admiralty) to publish some of the material contained in this article is acknowledged with thanks.

Bibliography.

[5] "Velocity Modulation Valves," L. F. Broadway, C. J. Milner, D. R. Petrie, W. J. Scott and G. P. Wright, *J.I.E.E.*, Vol. 93, Part IIIA, p. 855, No. 5, 1946.

[18] "Reflex Oscillators," J. R. Pierce and W. G. Shepherd, *Bell System Technical Journal*, Vol. 26, p. 460, July, 1947.

[19] "The CV35—A Velocity Modulation Reflection Oscillator for Wavelengths of About 10 cm," A. F. Pearce and B. J. Mayo, *J.I.E.E.*, Vol. 93, Part IIIA, No. 5, p. 918, 1946.

[20] "The Cavity Magnetron," H. A. H. Boot and J. T. Randall, *J.I.E.E.*, Vol. 93, Part IIIA, No. 5, p. 928, 1946.

[21] "Ultra-High Frequency Modulation on Wave-Guides," H. Gutton and J. A. Ortusi, *J. Brit. I.R.E.*, October, 1947.

[22] "A Frequency-Modulated Magnetron for Super-High Frequencies," G. R. Kilgore, Carl I. Shulman and J. Kursham, *Proceedings I.R.E.*, Vol. 35, p. 657, July, 1947.

[23] "Low-Power Resonant-Segment Magnetrons for Centimetre Waves," J. C. Dix and E. C. S. Megaw, *J.I.E.E.*, Vol. 93, Part IIIA, No. 10, p. 1585, 1946.

Book Reviews

"Communication Circuit Fundamentals for Radio and Communication Engineers." Carl E. Smith, B.Sc., M.S., E.E. McGraw-Hill Publishing Co., Ltd., London. 401 pp. 190 ill. 42s. 6d.

This book was written to assist American students who are reading by means of home study courses for the more advanced telecommunication examinations. In the U.S.A., correspondence courses are used more extensively than in this country. The author, Carl E. Smith, who has had many years of experience in this aspect of teaching, has clearly given much thought to the best methods of arranging and presenting his subject—one which in the hands of a poor exponent can make dreary reading—in a manner likely to attract and encourage home students. The book was not compiled to fit the English system of technical education, but does, in fact, cover much of the network and thermionic valve theory for the syllabus of the City and Guilds of London Institute examinations in Telecommunications (Principles) up to, and including, the fourth year. The physical aspects are emphasised wherever possible, usually by short illustrated accounts of practical applications of theoretical results.

The first four chapters are comparatively elementary and deal with electrical quantities and their use in D.C. circuits. Chapter 6, entitled "Generator and Motor Action," is the least satisfactory in the book as the field it attempts to survey is too wide. Types of D.C. measuring instruments, relays, and D.C. generators and motors—omitting the essential concept of "back E.M.F."—are all discussed in this one short chapter. A more thorough treatment of instruments alone would have been of more value to most students. From Chapter 7 the author settles to a steady development of network theory, which culminates in Chapter 15 in the classical theorems of Thevenin, Norton, the Reciprocity theorem and Maximum Power Transfer theorems. It is invigorating to find considerable care devoted to the sketching of reactance curves of complex series-parallel networks, a rough method of analysis most useful in more advanced network investigations.

The last five chapters are devoted to thermionic emission and its applications. The diode, the triode, various multi-element tubes and the cathode ray tube are discussed in turn. This section of the book is intended to form a link with a later volume on radio aspects of telecommunications.

Students will appreciate the summary at the end of each chapter, and the exercises (to which skeleton answers appear at the back of the book).

The book is produced in the excellent manner usually associated with the McGraw-Hill Company, and would form a valuable addition to the library of most students of telecommunications. C. F. F.

"Workshop Engineering Calculations and Technica Science." Vol. 2. J. T. Stoney, B.Sc English Universities Press Ltd., London. 212 pp. 177 ill. 12s. 6d.

This, the second volume of this work, completes the second and third years' course in workshop engineering, as required by the City and Guilds and other technical institutes. The book contains 16 chapters followed by tables, logarithms and trigonometrical ratios. The chapters deal principally with materials, simple machines, forces, motion, energy, heat treatment and elementary geometry, trigonometry and algebra, but the arrangement of the material is open to criticism. For example, it seems odd that a chapter on Heat Treatment of Metals should be preceded by one on Velocity and followed by one on Logarithms. Two excellent features of the book, of particular value to students, are the large number of worked examples and the exercises that follow each chapter. The answers to the numerical exercises are given at the end of the book.

The book is written in a simple and clear style, the standard of reproduction is excellent and it will be found very useful by the grade of student for whom it has been written.

R. S. P.

The Use of a Piston Attenuator for Cable Testing in the Frequency Range 1-30 Mc/s

E. C. H. SEAMAN, B.Sc.(Eng.), A.M.I.E.E., D. A. CROW, B.Sc.(Eng.), A.C.G.I., A.M.I.E.E., and C. G. CHADBURN†

U.D.C. 621.315.212.001.4 : 621.317.33/34

The piston attenuator has become a familiar tool for use at frequencies of 1,000 Mc/s upwards. This article describes a device which has been developed utilising the same principle for insertion loss measurements on the more recently developed types of high-frequency coaxial cables, in particular the 0·975-in. coaxial pairs of the new London-Birmingham television cable, where it has been used for acceptance testing measurements in the range 1-30 Mc/s. For this purpose, piston attenuators have been incorporated in a portable signal generator providing crystal-controlled spot frequencies in that range.

Introduction.

IN the acceptance testing of completed repeater sections of coaxial cable, the tests made on the coaxial pairs include measurements of attenuation; for this purpose two coaxial pairs are usually connected together at one end of the repeater section and the attenuation* of the loop circuit so formed is measured at the other end of the section. Coaxial pairs of $\frac{3}{8}$ in. diameter are utilised and tested at frequencies up to 3 Mc/s, where techniques for measuring attenuation are well established. On the other hand, the 0·975-in. coaxial pairs of the new London-Birmingham television cable[1] may ultimately be utilised at much higher frequencies. It was, therefore, decided to test these coaxial pairs up to 30 Mc/s, and it has been necessary to provide apparatus for the measurement of attenuation at such frequencies. The loss to be measured, for a looped circuit over a repeater section of the maximum permissible length (3·25 miles), increases from about 10 db. at 1 Mc/s to about 58 db. at 30 Mc/s. In considering the method of measurement to be used, it was borne in mind that the measurements have to be made on a routine basis in the field; the apparatus must be portable and easy to operate. The method adopted is based on the use of a calibrated piston attenuator incorporated in a signal generator that has been designed for the purpose. The loss to be measured varies rapidly with frequency, so the frequency of test must be accurately known. To avoid the need for a separate crystal frequency-check unit, the signal generator provides outputs at spot frequencies which are harmonics of the frequency of a crystal oscillator incorporated in it. The principle of operation of piston attenuators will first be briefly described.

Principles and Characteristics of Piston Attenuators

Piston Attenuator as form of Waveguide.

In a piston attenuator a length of waveguide is used as a means of obtaining a known attenuation. The simplest kind of waveguide consists of a metal tube of rectangular or circular cross-section. Electromagnetic fields can exist in such a waveguide in specific configurations or *modes*; these are divided into two main classes, E modes and H modes. In E modes there is a longitudinal component of electric field but no longitudinal component of magnetic field, and conversely for H modes. Within each of the main classes, particular modes are designated by suffixes, for example, $E_{0,1}$, which represents the simplest E mode, and is the one employed in the apparatus to be described. The behaviour of the electromagnetic field in a waveguide varies according to the mode, the frequency and the dimensions of the guide. For each mode in a guide of given cross-sectional shape and dimensions, there is a particular frequency, the critical or cut-off frequency, above which electromagnetic energy is freely propagated in the form of a progressive wave, with a phase shift proportional to distance, as in a transmission line. Ideally, if the walls of the guide had infinite conductivity, there would be no attenuation. On the other hand, at frequencies below the critical frequency the field is rapidly attenuated with increase of distance from the source of excitation. This would be true even if the walls of the guide were perfectly conducting; the attenuation is not primarily due to ohmic losses in the walls of the guide, although the resistance of the walls may contribute a little additional attenuation. The attenuation coefficient, or rate of decay of the field in decibels per unit length, can be calculated from theoretical considerations. In a guide with perfectly conducting walls operated below the critical frequency, the phase of the field components does not change with distance along the guide.

A piston attenuator consists of a length of waveguide with an input element for exciting a field in a particular mode, an output element for extracting power at a point further along the guide, and arrangements for varying the distance between the input and output elements. The dimensions of the guide are such that the operating frequency is below the critical frequency. The nature of the input and output elements depends on the mode; for the $E_{0,1}$ mode in a circular guide, disks are used as shown diagrammatically in Fig. 1. The output element is usually mounted in a tube of smaller diameter than the guide, fitting closely within it like a piston, and this gives the means of varying the distance between the input and output elements and thus varying the

† In the order as listed the authors are: Senr. Exec. Engineer, Radio Experimental and Development Branch; Senr. Exec. Engineer, Research Station; and Assistant Engineer, Radio Experimental and Development Branch.

* "Attenuation" is used as a convenient descriptive term; the quantity actually measured is the insertion loss of the circuit between resistances equal to the nominal characteristic impedance of the coaxial pair (75 ohms in Post Office practice).

[1] "The London-Birmingham Television Cable," H. Stanesby and W. K. Weston, *P.O.E.E.J.*, Vol. 41, p. 183.

attenuation. The input and the output of an $E_{0,1}$ piston attenuator appear as small capacitances ; if it is desired to obtain 75-ohm resistive input and output impedances, 75-ohm resistors may be connected across the input and output circuits near the disks.

Provided that the loss always exceeds a certain minimum value, the change of output in decibels corresponding to a given change in setting can be found by multiplying the constant attenuation

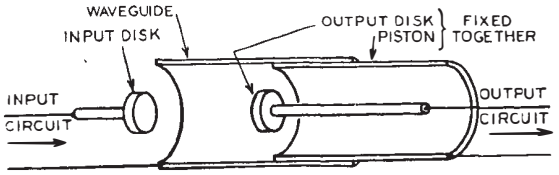


FIG. 1.—BASIC FEATURES OF AN $E_{0,1}$ PISTON ATTENUATOR.

coefficient for the field by the distance through which the piston is moved. This relation does not hold at settings of low loss, when the input and output elements are close together, for two reasons. Firstly, the input element sets up field components in a number of unwanted modes in addition to the intended operating mode, and the different modes have different attenuation coefficients. The operating mode is so chosen, and the input element is so designed, that any other modes likely to be produced have a much higher attenuation coefficient than the operating mode and their effect decreases rapidly with distance along the guide. Secondly, the waveguide operated below the critical frequency is essentially a reactive device, and is necessarily mis-terminated when used to supply power to a resistive load. The piston attenuator, therefore, behaves like any other attenuator that is terminated in impedances not equal to its characteristic impedance ; the actual changes of loss are equal to the nominal changes if the loss is always large, but not otherwise. In any piston attenuator there is thus a minimum loss, below which it is inconvenient to use the attenuator, since the simple relation between loss and piston position no longer holds.

Use of a Piston Attenuator for Loss Measurement.

It is evident that a piston attenuator gives a means of varying the magnitude of a signal by known amounts, but, unlike a resistive attenuator, it does not give an insertion loss of known value variable from zero upwards ; it cannot, therefore, be used for the measurement of insertion loss by direct substitution. It is convenient to combine the source of power and the piston attenuator in a single unit ; the signal generator so formed can then be used, in conjunction with a suitable receiving unit, to measure insertion loss in the following way. The signal generator is first connected through the circuit under test to the receiving unit with the piston attenuator set at minimum, and the indication of the receiving unit is noted. The circuit under test is then removed, and the loss in the piston attenuator is increased so that the receiving unit gives the same indication as before. The loss of the circuit under test can then be calculated from the change in setting of the piston attenuator. It should be noted that the receiving unit is only required to give repeatedly the same indication for the same input ; it is not required to measure the input that it receives. The apparatus to be described operates on these general lines, but, as discussed later, the signal generator has a fixed output from a preset piston attenuator in addition to the variable output from the main piston attenuator, and this simplifies the operating procedure.

DESCRIPTION OF THE EQUIPMENT

Electrical Characteristics of the Piston Attenuator.

The main piston attenuator consists of a length of circular waveguide of $\frac{7}{8}$ in. nominal diameter, which is excited in the $E_{0,1}$ mode by means of a disk at one end. Power is extracted from the guide by a similar disk, whose distance from the input disk can be varied by means of a screw with 24 threads per inch. A 75-ohm resistor is connected between the output disk and the sleeve of the piston to give a resultant output impedance close to 75 ohms.

The critical frequency for the $E_{0,1}$ mode in a $\frac{7}{8}$ in. diameter guide is about 10,000 Mc/s, so the operating frequencies are very much lower than the critical frequency. It can be shown theoretically that under these conditions the attenuation coefficient for the field is 47·744 decibels per inch.

The attenuation per revolution of the screw can conveniently be called the " attenuation factor " of the piston attenuator ; for the $\frac{7}{8}$ in. diameter $E_{0,1}$ attenuator, with a screw having 24 threads per inch, the attenuation factor is 1·9893 decibels per revolution. The attenuation coefficient is inversely proportional to the diameter of the guide, and the figures given must be modified accordingly if the guide diameter differs from 0·875 in.

Provision of Preset Attenuator.

The screw controlling the position of the piston in the main piston attenuator necessarily has a fine pitch to give high setting and reading accuracy, and it follows that the number of revolutions of the driving spindle required to change the output by a given amount is correspondingly large. In the simple method of measuring loss with a piston attenuator, described above, the variable attenuator has to be adjusted through the whole range of loss under test to compare the readings for the receiving unit indicator with the test circuit in series and removed. The measurement of a loss of, say, 40 db., would involve turning the spindle through about 20 revolutions between the two observations and perhaps also repeating this several times to establish confidence in the comparison. This would not only be tedious but the appreciable time interval between the two observations would accentuate the risk of error due to changes in the signal generator output or the receiving unit sensitivity such as can arise from variations in supply voltages.

To avoid these difficulties, the signal generator has a second piston attenuator which can be preset to give an output equal to that of the main attenuator at a particular " reference " setting. The two piston

attenuators have the same waveguide diameter and the same arrangement of input and output disks, but whereas the main attenuator has an accurate screw drive giving a large range of movement of the piston, the preset attenuator has only a simple screw adjustment, with a locking arrangement, for a limited range of movement. The input disks of the two attenuators are connected in parallel, so that any change of input affects both outputs equally. The outputs from the main piston attenuator and the preset piston attenuator appear at coaxial plugs marked "variable output" and "fixed output" respectively. The flexible coaxial leads connecting the two attenuators to the associated plugs are made of equal length, so that variation of attenuation with frequency in these leads does not give rise to any error.

With these facilities, the procedure for the measurement of insertion loss is as follows (Fig. 2). The input

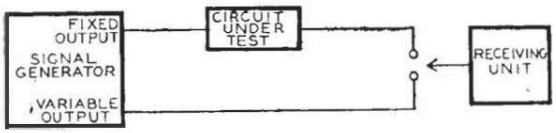


FIG. 2.—ARRANGEMENT FOR MEASURING INSERTION LOSS.

of the circuit under test is connected to the fixed output plug, and with the aid of a receiving unit the main attenuator is adjusted so that the variable output from the signal generator is equal to the output from the circuit under test. To compare the two outputs it is only necessary to change over the lead from the receiving unit from the one to the other, and this can be done very quickly. Repeated change-overs to permit refinement of adjustment and confirm the comparison can be done equally quickly. When the adjustment has been made, the loss of the circuit under test can be found from the reading of the main piston attenuator. It is not necessary to know the actual magnitude of the output from the signal generator, and the latter is not designed to provide an accurately known output.

Circuit Outline of Signal Generator.

The signal generator is designed to operate at any one of twelve frequencies, from 1 Mc/s to 5 Mc/s in steps of 1 Mc/s, and from 10 Mc/s to 40 Mc/s in steps of 5 Mc/s; the required frequency is selected by means of a single control which operates all the switches concerned with frequency-selection. A block schematic diagram is shown in Fig. 3.

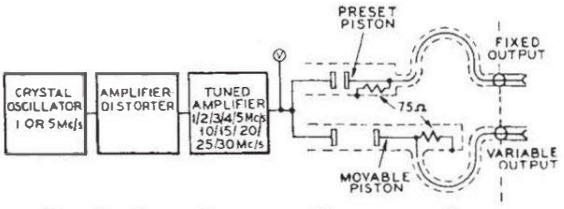


FIG. 3.—BLOCK SCHEMATIC DIAGRAM OF PISTON ATTENUATOR CONTROLLED SIGNAL GENERATOR.

The first stage is a conventional crystal oscillator operating at 1 Mc/s or 5 Mc/s. The 1-Mc/s crystal is used for output frequencies from 1 Mc/s to 5 Mc/s, and the 5-Mc/s crystal for output frequencies from 10 Mc/s to 40 Mc/s.†

The oscillator is followed by an overdriven amplifier which generates harmonics. A two-stage amplifier follows, having anode circuits tuned to the desired output frequency, the appropriate inductors and capacitors being selected by switches.

The second tuned amplifier stage is connected to the input disks of the two piston attenuators. A diode valve-voltmeter circuit is provided to give an indication of the voltage at this point. This facility is intended to assist in checking that the instrument is in working order; it is not intended to be used as a means of obtaining an accurately known output.

Supplies at 250V D.C. and 6·3V A.C. or D.C. are required. The incoming supply leads are filtered to minimise leakage of R.F. energy along these leads.

General Layout.

Fig. 4 shows the signal generator complete with its

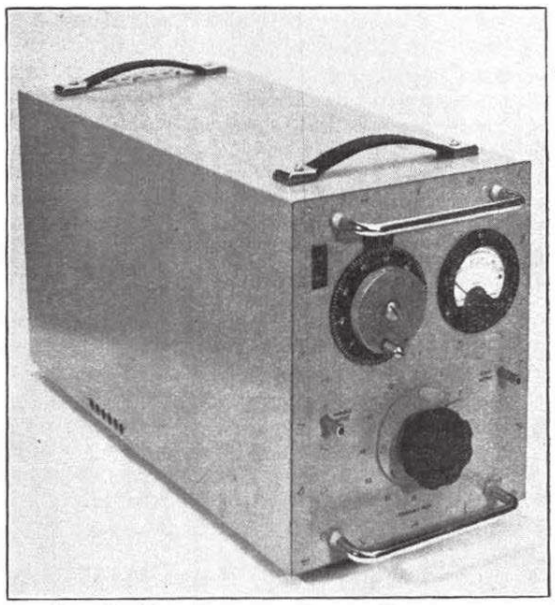


FIG. 4.—THE COMPLETE SIGNAL GENERATOR.

cover, and Fig. 5 shows it with the cover removed. The front panel is of $\frac{1}{8}$ in. brass and carries the controls, the output plugs and the output indicator meter. Attached to the panel is the chassis, which is a rectangular copper box containing the oscillator, amplifier and power filter circuits. On the top of the chassis, and towards the rear of it, is mounted a rectangular screening box, which screens the leads connecting the tuned amplifier to the input disks of the piston attenuators, and houses the diode associated with the output indicator. This screening box supports the preset piston attenuator and the rear end of the

† In addition to frequencies in the range 1-30 Mc/s, which are specifically required for cable testing, frequencies of 35 Mc/s and 40 Mc/s are available for other possible applications.

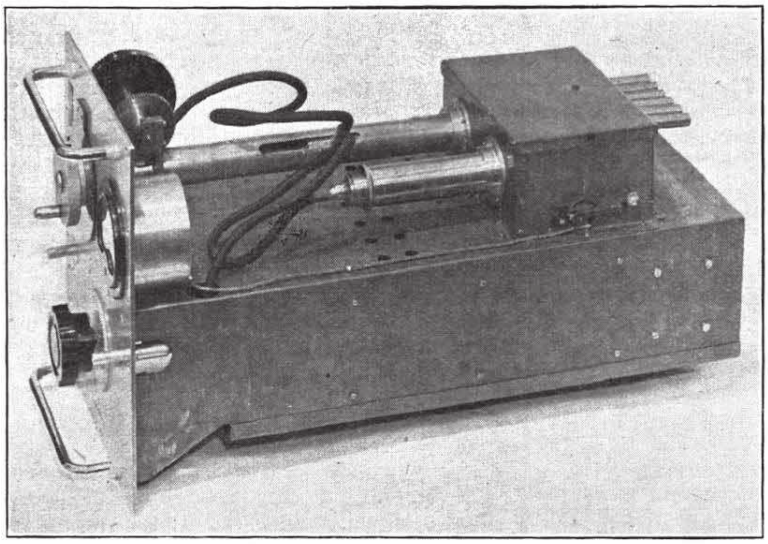


FIG. 5.—THE SIGNAL GENERATOR WITH COVER REMOVED.

main piston attenuator housing ; the front end of the latter is fixed to the front panel.

The assembly so far described is inherently screened. An outer screen is provided by the cover, which is made of copper in the form of a box open at the front end. The open end is reinforced with brass angle to form a mask to which the front panel is screwed.

Metal tubes, $\frac{3}{8}$ in. in diameter and about 2 in. long, are used for ventilation. A set of six tubes, projecting to the rear from the screening box on the top of the chassis, can be seen in Fig. **5**; the ends of further tubes, fixed inside the cover, can be seen in Fig. **4**. From the point of view of leakage of R.F. energy, the tubes are waveguides operated well below the cut-off frequency, and they have a very large attenuation. A similar device is used to prevent leakage where the operating rod for the frequency selector switches is connected to its control knob ; a coupling rod of insulating material passes through a metal tube fixed to the front panel. The power supply input socket is mounted in a circular housing at the rear of the chassis ; this housing passes through a hole in the cover, and a clamping ring is screwed on after the instrument has been inserted in the cover.

Construction of Attenuators.

Both piston attenuators can be seen in Fig. **5**. The more important features of the main piston attenuator will be described with reference to the simplified sectional drawing given in Fig. **6**.

The housing (1) is a 12-in. length of brass tube of $\frac{7}{8}$ in. internal diameter ; the part of the tube extending about four inches from the rear end (the right-hand end in Fig. **6**) forms the waveguide of the piston attenuator, and the remainder acts as a guide for the piston and a support for the drive mechanism. The input disk (2) is carried by a distrene mounting (3) at the rear end of the housing. The output disk (4) is integral with the piston conductor (5), which is supported in the piston sleeve (6) by distrene pieces (7, 8). The piston conductor and the piston sleeve form a coaxial circuit, which is extended by way of the cable adaptor (9) and a length of flexible coaxial cable to the output plug on the front panel ; a 75-ohm 0·1-watt resistor is connected across the output circuit inside the piston. The cable adaptor (9) travels in a longitudinal guide slot in the housing (1) and serves as a key to prevent rotation of the piston. The guide slot limits the travel of the piston to three inches, corresponding to an attenuation of about 140 decibels. Fixed to the piston sleeve is the steel motion screw (10) which has **24** threads per inch. The front of this screw enters a phosphor-bronze driving nut (11) carried in the driving sleeve (12), which is rigidly connected to the driving knob (13). Thrust bearings (14, 15), tensioned by the spring (16), permit the driving sleeve to rotate with a minimum of friction, but prevent axial movement of the sleeve relative to the attenuator housing. The setting of the attenuator is indicated, in terms of revolutions of the driving sleeve, by means of a dial and a worm-driven counter. The dial (17) is rigidly fixed relative to the driving sleeve, and is engraved to indicate hundredths of a revolution. Complete revolutions are read on the drum (18), which is driven by a worm wheel engaging with a worm on the outside of the driving sleeve.

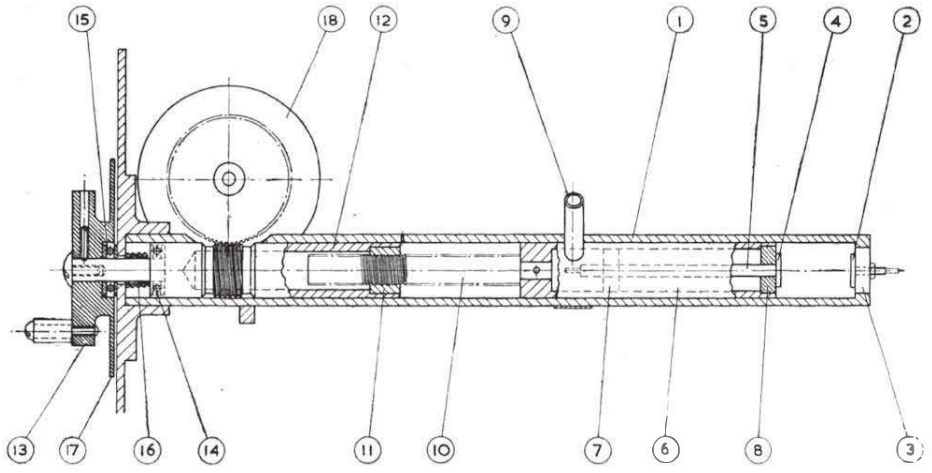


FIG. 6.—SECTIONAL VIEW OF MAIN PISTON ATTENUATOR.

The preset piston attenuator is identical with the main piston attenuator so far as features affecting the attenuation for a given position of the piston are concerned. It is, however, arranged for adjustment over a limited range only, and the piston can be locked in position after adjustment, by the knurled ring which can be seen in Fig. **5**.

Adjustment and Performance of the Equipment

Minimum Setting of Main Piston Attenuator.

Fig. **7** is a typical graph showing approximate attenuation factor (db. per revolution of the driving spindle) plotted against setting for the main piston attenuator. The attenuation factor is substantially constant at settings greater than 10·00; that setting is, therefore, taken as the minimum to be normally used, and is described as the reference setting. The determination of the precise value of the attenuation factor is discussed later.

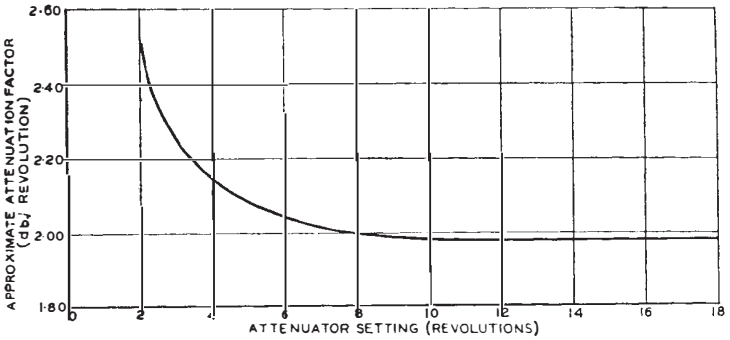


Fig. 7.—Variation of Attenuation Factor with Setting of Main Attenuator.

Alignment.

In the initial alignment of each instrument, the main piston attenuator is set at a reading of 10·00 and the preset piston attenuator is adjusted so that the output at the "Fixed Output" plug is equal to that at the "Variable Output" plug. This adjustment can be made at any convenient frequency, and the two outputs are then equal at all frequencies.

At each frequency, the preset tuning of the anode circuits of the two tuned amplifier stages is adjusted to give maximum reading on the output indicator. This adjustment is made in the initial alignment, but requires an occasional check subsequently.

Backlash in the Piston Attenuator.

Backlash in the main piston attenuator, which would cause the output at any given setting to depend upon the direction of approach to the setting, can be made negligible if special care is taken in the screw-cutting and fitting of the motion screw and driving nut. If special care is not taken, backlash may not be negligible, but no error in measurements will result if the final adjustment of the attenuator is always made in the same direction.

Output.

The output at the "Fixed Output" plug, or the output at the "Variable Output" plug at the reference setting of the main attenuator, increases with frequency over the range used for cable testing, 1-30 Mc/s. The range of output is from about −53 db. to −24 db. relative to 1 milliwatt into 75 ohms. Although a variation of output with frequency is unusual in a source of test signal, it is not inconvenient in this instance, since the method of measuring loss does not require a knowledge of the actual output. The increase of output with frequency is in fact useful, since the loss to be measured in cable testing increases with frequency.

The output may contain a component at any harmonic of the crystal frequency. As the signal generator is intended to be used with a highly selective receiving unit, the unwanted components are unlikely to cause any difficulty; most of them are 40 db. or more below the wanted output.

Maximum Loss Measurable.

The maximum loss that can be measured depends, not only on the magnitude of the reference output from the signal generator, but also on the sensitivity and signal/noise ratio of the receiving unit, which determine the lowest input at which sufficiently small changes of input can be detected. A typical receiving unit comprises a radio receiver of the "communications" type, slightly modified to give an indication of the input level on a meter, and having a 10-db. 75-ohm pad at the input to provide an input impedance close to 75 ohms. Using this receiving unit, the maximum loss that can be measured, if a change of input to the receiving unit of 0·025 db. is to be detectable, varies from about 68 decibels at 1 Mc/s to about 88 decibels at 30 Mc/s.

Screening.

The effectiveness of the screening of the signal generator was checked by exploration with a small search coil connected to the input of a sensitive radio receiver tuned to the signal generator output frequency. Slight leakage was found near the output indicator meter, but elsewhere no leakage could be detected. An exceedingly small amount of leakage between the signal generator and the receiving unit can, however, cause a significant error in the measurement of large losses; leakage equivalent to an input to the receiver 57 db. below the wanted input may, according to the phase shift in the circuit under test and the phase of the leakage relative to the signal, cause an error up to 0·025 db. It is, therefore, desirable for the receiving unit to have screening and power supply filtering arrangements similar to those of the signal generator, particularly if the two instruments are to be connected to the same power supplies.

Value of Attenuation Factor.

Simple production methods enable the bore of the main piston attenuator to be made reasonably uniform, but do not readily give a pre-determined diameter. It is, therefore, desirable to determine the attenuation factor for each instrument. This can be done by calculation, based on measurement of the diameter, and also by reference to other methods of measuring loss. The consistency between the results of different methods indicates that the attenuation coefficient can be determined to an accuracy of 2 parts in 1,000.

Accuracy of Measurement of Loss.

In addition to the error due to inaccurate knowledge of the attenuation factor, some error will be incurred in the actual process of measurement. This is not likely to exceed 0·1 db., and the magnitude of the total error in a measurement is, therefore, not likely to exceed 2 parts in 1,000 of the loss in decibels measured, plus 0·1 db.

Application.

Signal generators of the type described have been used throughout the acceptance testing of the London-Birmingham television cable for the measurement of the attenuation of the 0·975-in. coaxial pairs; they have given reliable service and have been found convenient and easy to operate.

Book Reviews

" Progressive Mathematics." P. Clyne, A.C.G.I., A.M.I.E.E. Chapman & Hall. 270 pp. 121 ill. 15s.

This book is a welcome addition to the literature on mathematics particularly intended for engineering students. It collects together, as far as is known for the first time, a number of modern methods of approach which have been introduced by the more progressive teachers during the last twenty years or so—methods which appeal particularly to the student of engineering and which teach him how to understand and use his mathematics for the solution of engineering problems.

Although it is agreed that graphical illustrations and short, snappy proofs are useful adjuncts in presenting a subject for the first time, it cannot be agreed—as the writer of the foreword and the author both suggest—that such proofs can entirely replace the longer and more involved but invariably sounder proofs based on the more powerful methods of mathematical analysis.

The professional engineer—who, of course, does not pursue mathematics for its own sake, but wants to use it as a tool—needs substantially more than the relatively superficial knowledge of the subject which this book provides—but for those who do not aspire to full professional status, it is possible that the book may suffice in itself; certainly, the student is much more likely to grasp the more rigid analytical method if he has been helped to understand all that is involved in the problem by the use of graphical illustrations when the subject is first presented.

In view of the author's excellent graphical treatment of algebraic, trigonometrical and hyperbolic functions and their differentiation, it is somewhat disappointing that he has omitted to use the same approach to differential equations. The graphical approach to differential equations gets rid, at the outset, of a whole host of the usual difficulties of students who approach this subject by the analytic method of treatment—difficulties, which, if not removed early, continue to obstruct the student's progress well beyond the beginner stage. This omission is all the more surprising since the author appears to have been studying mathematics at the Imperial College at the time when Levy was doing so much to encourage the graphical approach to the study of differential equations.

This method of approach could easily have been introduced in Chapter 10, para. 92. Fig. 40 is itself an illustration of the graphical representation of a differential equation, and this fact only needs to be pointed out in passing, referring back to it in Chapters 15 and 18, and developing it a little further. It is most noticeable, in fact, that Chapter 18, entitled " More Differential Equations," does not contain a single diagram.

The author may wish to adopt this suggestion or a modification of it in a later edition. It would certainly add substantially to the value of the book.

In conclusion, the book can be thoroughly recommended to engineering students, particularly to adult students who are commencing a study of more advanced mathematics. But for those who need more than a superficial knowledge of mathematics, the treatment will need to be consolidated by the parallel reading of a text book dealing with the subject on more rigid analytical lines.

F. C. M.

" Accumulator Charging." W. S. Ibbetson. Sir Isaac Pitman & Sons, Ltd. 190 pp. 41 ill. 10s.

The first edition of this book was published in 1928 and in this, the 10th edition, the author has been able to accomplish a complete revision, including some rearrangement of the subject-matter. Elementary D.C. theory is dealt with in the first two chapters, followed by chapters on the elements of accumulators, the effect of charge and discharge and capacity under various conditions, leading to detailed consideration of the construction and characteristics of modern accumulators in Chapter VI. The remainder of the book is devoted to battery charging and the maintenance of batteries, including repairs and workshop facilities necessary. The rather sketchy treatment of rectifiers for charging is explained by the author, " Unlike most of the D.C. charging units the construction of A.C. appliances is beyond the range of the ordinary electrician and they are best bought to suit the consumer's specification direct from the manufacturers." Even so, the almost universal use of A.C. warrants fuller treatment.

A useful chapter on Alkaline Cells is included and appendices give the syllabus for City & Guilds Motor Vehicle Electricians' Course, with selected questions from recent examinations and a suggested syllabus for Head Colliery Lamp-men responsible for maintenance of miners' battery lamps.

A book not over-burdened with theory for the practical electrician dealing with secondary batteries of the smaller type, it contains much useful information which should help towards a better understanding of the often neglected accumulator.

W. T. G.

A Simple Phase Measuring Circuit

R. A. SEYMOUR†

U.D.C. 621.317.772

The author describes a circuit designed for comparative phase angle measurements between two sinusoidal signals of the same frequency, and gives a theoretical analysis of its operation. The circuit can be used for measurements on feedback amplifiers over the range 50 c/s to 200 kc/s and has an accuracy of ±1° between 0° and 60°. Angles from 60° to 90° can be measured directly but with rapidly diminishing accuracy, and for this range the use of an auxiliary phase-shift network is recommended.

Introduction.

THE circuit to be described is used in conjunction with an oscillator and selective measuring set to make comparative phase measurements between two sinusoidal signals of the same frequency, such data being required, for example, in feed-back amplifier investigations. The general principle of operation is to measure the magnitude of one signal, subtract from it the component in-phase with the other signal, and then to measure the magnitude of the remainder. The ratio between the two magnitudes gives a measure of the phase angle between the two signals.

Circuit Description.

The circuit employed is given in Fig. **1** for a system

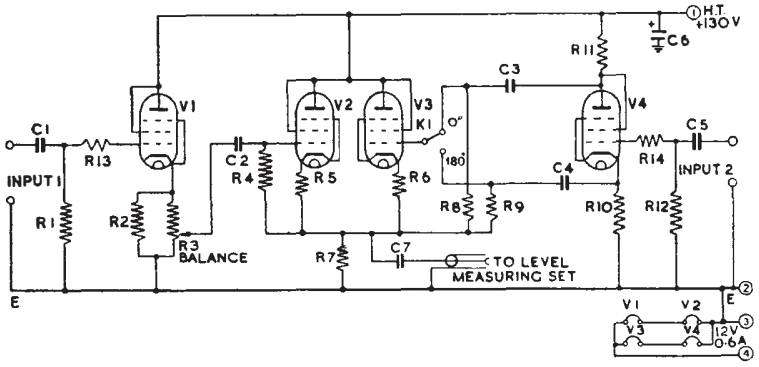


FIG. 1.—THE PHASE MEASURING CIRCUIT.

having two high impedance inputs, input **1** being normally used for the reference voltage, and input **2** for the voltage whose phase relation to the reference voltage is required. The potentiometer, R3, in the cathode of V1 permits variation of the magnitude of the reference voltage fed into the addition circuit V2 and V3. Switch K1 enables the voltage from input 2 to be given an alternative 0° or 180° phase-shift to ensure that the in-phase components of the two signals will cancel in the addition circuit.

Analysis of the Addition Circuit.

As a first step in analysing the phase measurement process, consider the addition circuit shown in Fig. **2** (*a*). This consists of two cathode-coupled valves, V2 and V3; e_1 and e_2 are the applied signals whose sum is required, and e_3 the output to be measured. In the equivalent circuit shown in Fig. **2** (*b*) it is assumed that the cathode impedance of each valve can be represented as a fixed resistance, which is added to the load resistance R. Then:—

$$R_1 i_1 + R_3 i_2 - e_1 = 0 \quad \ldots\ldots\ldots\ldots (1)$$

$$-R_2 i_1 + (R_2 + R_3) i_2 - e_2 = 0 \quad \ldots\ldots\ldots\ldots (2)$$

From (1) and (2), $i_2 = \dfrac{R_2 e_1 + R_1 e_2}{R_3 (R_1 + R_2) + R_1 R_2}$

and, $e_3 = R_3 i_2 = \dfrac{R_2 e_1 + R_1 e_2}{R_1 + R_2 + R_1 R_2 / R_3} \quad \ldots\ldots\ldots (3)$

If R_3 is large compared with $R_1 R_2$,

then, $e_3 = \dfrac{R_2 e_1 + R_1 e_2}{R_1 + R_2}$

Stability of Cathode Resistance with Level.

The validity of the foregoing paragraph depends on the equivalent cathode resistance being constant with the level of the applied signal. This is partly accomplished by means of the added series resistance R but, in addition, the choice of valve type is important.

A method of arriving at the order of change of cathode resistance with level is as follows. A general expression for the current i generated in a valve used in Class A is:—

$$i = a + be + ce^2 + de^3 +$$

where e is the input voltage.

Let $e = E \sin \omega t$.

Then, $i = a + bE \sin \omega t + cE^2 \sin^2 \omega t + dE^3 \sin^3 \omega t +$

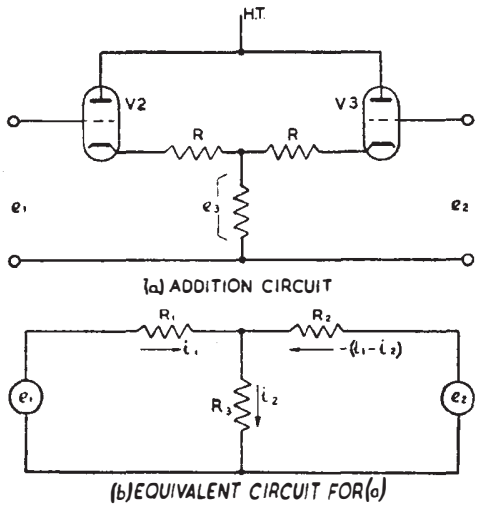


FIG. 2.—THE ADDITION CIRCUIT AND ITS EQUIVALENT NETWORK.

†*Executive Engineer, Research Station.*

$$= (a+cE^2/2+..) + (bE+\tfrac{3}{4}dE^3+..)\sin\omega t$$
$$-(cE^2/2+..)\cos 2\omega t - (dE^3/4+..)\sin 3\omega t$$

If a selective amplifier is used at the output then only the fundamental term $(bE+\frac{3}{4}dE^3+..)$ need be considered, and it can be seen that, as a first approximation, the percentage change of cathode resistance will not exceed three times the change in percentage of third harmonic with change of input voltage. In addition, V2 and V3 are used in triode form to ensure that the third harmonic product is kept to a minimum.

Operation of Circuit.

The phase bridge will need to have a selective amplifier and level measuring set, or voltmeter connected to its output circuit, this measuring equipment being free from interference by unwanted signals over a 40 db. range of levels. The dependence of the accuracy of measurement of phase angle on the accuracy of level measurement is shown later.

To operate the set, consider the reference signal connected to input 1, and the test signal, whose relative phase is required, connected to input 2. Potentiometer R3 is initially at zero (i.e. no signal into V2) and the output meter set to its maximum reading. Potentiometer R3 is then operated to send a signal into V2, and if the reading on the output meter tends to increase, the switch K1 is used to reverse the phase of the test signal applied to V3. Potentiometer R3 is further adjusted until a minimum reading on the output meter is achieved. The ratio between the initial and final output readings is then used, as follows, to evaluate the phase angle.

Calculation of Phase Angle.

Let the input voltage to V2 $= e_1$ and the input voltage to V3 $= -e_2(\cos\theta + j\sin\theta)$. Initially, $e_1 = 0$, i.e., potentiometer R3 at zero.

Then from equation (3) the output voltage, e_3, will be,

$$e_3 = e_{31} = \frac{R_1}{R_1+R_2+R_1R_2/R_3}\cdot|e_2|$$

Now give e_1 a value by increasing potentiometer R3.

$$\text{Then, } e_3 = e_{32} = \frac{R_2e_1 - R_1e_2(\cos\theta + j\sin\theta)}{R_1+R_2+R_1R_2/R_3}$$
$$= \frac{R_2e_1 - R_1e_2\cos\theta}{R_1+R_2+R_1R_2/R_3} - j\frac{R_1e_2\sin\theta}{R_1+R_2+R_1R_2/R_3}$$

When a minimum balance is obtained by adjustment of potentiometer R3, then,

$$R_2e_1 = R_1e_2\cos\theta$$

$$\text{Hence, } e_{32} = \frac{R_1}{R_1+R_2+R_1R_2/R_3}\cdot|e_2\sin\theta|$$

$$\text{and, } e_{31}/e_{32} = \operatorname{cosec}\theta$$

$$\therefore \theta = \operatorname{cosec}^{-1} e_{31}/e_{32}$$

also, $\theta = \log \operatorname{cosec}^{-1} N/20$, where N is the difference between the initial and final readings expressed in decibels.

Let, $e_{31}/e_{32} = m$

Then, $\theta = \operatorname{cosec}^{-1} m$

and, $\dfrac{d\theta}{dm} = -\dfrac{1}{m\sqrt{m^2-1}}$

From this latter expression it can be observed that the greatest accuracy of voltage ratio measurement is required when the phase angle is approaching 90°.

With regard to the effect of harmonic production on the accuracy of measurement of the voltage ratio, it should be noted that when the error in the ratio is likely to be greatest, namely, around zero phase shift (i.e. when the change of voltage on the addition valves during balancing is greatest) the error caused in the measured phase angle is least. The opposite state of affairs occurs when the angle is around 90°, since the change of voltage on the valves is then at a minimum. The production of third harmonic in the addition circuit described does not exceed 1 per cent. at the maximum input level.

Performance.

In practice the circuit illustrated in Fig. 1 will maintain an accuracy of phase angle measurement within 1° from 0°-60°, over the frequency range 50 c/s-200 kc/s provided that the voltage ratio can be measured with an accuracy of 1 per cent. Angles from 60°-90° can also be measured directly but with a rapidly diminishing accuracy, e.g. a 1% inaccuracy of voltage ratio measurement, when the angle is in the region of 90°, will result in an error of 8°. An accurate measurement of angles in this range can, however, be obtained if one or other of the signals is given a known phase-shift by means of an auxiliary network, so that the resultant phase angle to be measured falls within the 0°-60° range. The input capacitances are of the order of 20 pF, and the maximum input level should not exceed 2 volts R.M.S.

The foregoing frequency limits are imposed on account of the physical properties of the components used in the particular model described. Provided that care is taken with the choice of components and the layout, there is no theoretical reason why this circuit should not be used over a considerably greater frequency range.

An advantage of the present method of measurement over that used in an H.F. phase meter recently described,[1] is that only two readings of the output meter are required against three, to evaluate a phase angle.

Note.—Since the design of this equipment an article[2] has been published describing a phase measurement circuit employing an addition circuit of similar principle but differing in detail. No theoretical analysis of the performance of the addition circuit is given.

[1] Duerdoth, W. T. "A Phase-meter for the Frequency Band 100 kc/s-20 Mc/s. *P.O.E.E.J.*, Vol. 42, p. 43.

[2] F. A. Benson and A. ●. Carter. "A New Method of Measuring Phase Angle." *Journal of Scientific Instruments*, Vol. 26, No. 8, p. 285.

The Calculation of Phase Constant from Small Differences of Open and Closed Impedance

P. R. BRAY, M.Sc.(Eng.), A.M.I.E.E.†

U.D.C. 621.392.4

A method is given for calculating the phase constant of a line where the differences between open and closed impedance bridge readings are small. Under certain conditions, the significance of these small differences may be lost by the direct application of standard formulae unless tables to at least seven figures are employed.

Introduction.

THE phase constant, in rads./unit length, on a line of length l may be found from the expression

$$2\beta l = n\pi + \tan^{-1}\frac{2\sqrt{M}\sin\mu}{1-M} \text{ rads.} \quad \ldots\ldots (1)$$

$$\text{where } M = Z_e/Z_i \text{ and } \mu = \frac{\phi_e-\phi_i}{2},$$

$Z_e/\underline{\phi_e}$ and $Z_i/\underline{\phi_i}$ being the sending end impedances with the far end closed and opened, respectively. There is normally little difficulty in applying this equation. Tan^{-1} may be positive or negative, depending on the sign of $(1-M)$ and of μ (should ϕ_e or ϕ_i be negative, it must be prefixed by the appropriate sign). There is a possible ambiguity about the value of the factor n (=0, 1, 2, etc.), which is resolved either by the inspection of the sequence of the results obtained at a number of frequencies or by using the estimated figure in the calculation of one of the primary constants (such as capacitance C) whose order is known.

It will be seen, however, that for frequencies at which the line is becoming electrically long, i.e., where $Z_e \to Z_i$ and $\phi_e \to \phi_i$, both $(1-M)$ and $\sin\mu$ become small quantities based on the difference of much larger quantities. Unless tables are used, having significant figures adequate for the sensitivity of the measuring apparatus, the $\tan^{-1}$ term will be determined to a poor degree of approximation.

At audio and higher frequencies, it is found that n usually has a value sufficiently high to make an approximate value of $\tan^{-1}$ tolerable. On the other hand, as the frequency is decreased through the low-audio and sub-audio range, the angle of the characteristic impedance tends to a value of $-45°$ and the angle of the propagation constant to $+45°$, this latter fact signifying that the phase constant in radians per unit length is approximately equal to the attenuation constant in nepers per unit length, i.e., on a 27·3 db. line which is fairly long electrically, $2\beta l \doteq 2\pi$ rads. Since n is small, it becomes correspondingly more important to compute the $\tan^{-1}$ term accurately. A method of doing this by utilising bridge differences directly will be developed, but at the outset it is thought that a brief description should be given of the type of bridge suitable for line impedance measurements at low frequencies.

The Series Artifice Bridge.

Partly from consideration of the design of the input circuit of the bridge detecting apparatus, it is preferable that an equal-ratio bridge should be employed. This being so, it is found that the values of the capacitances required in a simple series or parallel bridge become impracticably high at low frequencies. A method of overcoming this difficulty is to limit the series capacitance of the load by means of an added series capacitor, as in Fig. 1.

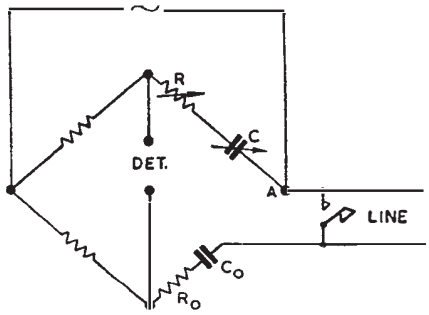


FIG. 1.—SIMPLIFIED CIRCUIT OF SERIES ARTIFICE BRIDGE.

This diagram is schematic only, and does not include screening details or refinements necessary for work on balanced cables. For coaxial cables, or other unbalanced types, such as single-core submarine telegraph cables, the point A is connected to the return or earth circuit. C_0 is the capacitor in series with the line, and R_0 an added series resistor, the value given (R_0) including the effective resistance of the capacitor at any particular frequency.

An initial balance is taken with the line input short-circuited, giving $R = R_0$ and $C = C_0$. The input short-circuiting key is then opened and two balances obtained, R_1, C_1 and R_2, C_2, with the far end of the line respectively short-circuited and open-circuited.

Then the series components R_e, C_e (or R_i, C_i) of the closed (or open) impedances are given by,

$$\left.\begin{aligned} R_e &= R_1-R_0, & C_e &= \frac{C_0C_1}{C_0-C_1} \\ R_i &= R_2-R_0, & C_i &= \frac{C_0C_2}{C_0-C_2} \end{aligned}\right\} \quad \ldots\ldots (2)$$

The bridge differences are thus equal to,

$$\left.\begin{aligned} \delta R &= R_i-R_e = R_2-R_1 \\ \delta C &= C_i-C_e = \frac{C_0^2(C_2-C_1)}{(C_0-C_1)(C_0-C_2)} \end{aligned}\right\} \quad \ldots\ldots (3)$$

† Senior Testing Officer, *H.M.T.S. Monarch.*

When δC is small, it should be calculated directly from the difference terms as indicated and not from C_e and C_f obtained separately.

The angles of the impedances are given by

$$-\phi_e = \cot^{-1}\omega C_e R_e, \quad -\phi_f = \cot^{-1}\omega C_f R_f$$

where $\omega = 2\pi \times$ frequency (in cycles per second), and the moduli by

$$Z_e = R_e \sec\phi_e, \qquad Z_f = R_f \sec\phi_f \quad \ldots\ldots(4)$$

ϕ_e and ϕ_f will normally be negative, since the reactance of a capacitor is negative. A positive angle would be indicated by a negative value for the capacitance derived from equation (2).

The characteristic impedance of the line is

$$Z_0 = \sqrt{Z_e Z_f} \text{ with an angle } \phi_0 = (\phi_e + \phi_f)/2 \ldots\ldots(5)$$

Formula for Phase Constant using Bridge Differences.

Let $2\beta l = n\pi + \theta$, where $\theta = \tan^{-1}\dfrac{2\sqrt{M}\sin\mu}{1-M}$

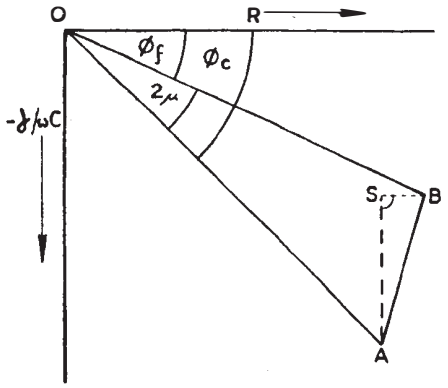


FIG. 2.—VECTORIAL REPRESENTATION OF OPEN AND CLOSED IMPEDANCES.

and in Fig. 2 let OA and OB illustrate the closed and open impedance vectors :—

In the triangle OAB

$$AB^2 = OA^2 + OB^2 - 2.OA.OB\cos 2\mu$$
$$= OA^2 + OB^2 - 2.OA.OB + 4.OA.OB\sin^2\mu$$
$$\therefore\ 4\,(OA/OB)\sin^2\mu = \frac{AB^2-(OA-OB)^2}{OB^2}$$

But $\theta = \tan^{-1}\dfrac{2\sqrt{M}\sin\mu}{1-M}$

$$= \tan^{-1}\frac{2\sqrt{OA/OB}\sin\mu}{1-OA/OB}$$

Then, $\tan^2\theta = \dfrac{4(OA/OB)\sin^2\mu}{(1-OA/OB)^2} = \dfrac{AB^2-(OA-OB)^2}{(1-OA/OB)^2.OB^2}$

$$= \frac{AB^2-(OA-OB)^2}{(OB-OA)^2} = \frac{AB^2}{(OB-OA)^2} - 1$$

$$\therefore\ \sec^2\theta = \frac{AB^2}{(OB-OA)^2}$$

or $\cos\theta = \pm\dfrac{OB-OA}{AB}$

$$= \pm\frac{\text{Difference of moduli of } Z_e \text{ and } Z_f}{\text{Modulus of vector difference of } Z_e \text{ and } Z_f} \ldots\ldots(6)$$

$$AB^2 = AS^2 + BS^2 = (1/\omega C_e - 1/\omega C_f)^2 + (R_f - R_e)^2$$
$$= \left(\frac{C_f - C_e}{\omega C_e C_f}\right)^2 + \delta R^2$$

Writing $R_e R_f = R_g^2$, $C_e C = C_g^2$, where suffix g signifies geometric mean,

$$AB = \sqrt{\frac{\delta C^2}{\omega^2 C_g^4} + \delta R^2} = \frac{\sqrt{\delta C^2 + \omega^2.\delta R^2.C_g^4}}{\omega C_g^2} \ldots(7)$$

For values of μ of 3° or less, an error of less than 0·5 per cent. is involved in writing

$$\sin\mu \doteq \tfrac{1}{2}\sin 2\mu \doteq \tfrac{1}{2}\tan 2\mu$$

$$\tfrac{1}{2}\tan 2\mu = \tfrac{1}{2}\tan(\phi_e - \phi_f)$$
$$= \tfrac{1}{2}\cdot\frac{\tan\phi_e - \tan\phi_f}{1 + \tan\phi_e\tan\phi_f}$$
$$\doteq \tfrac{1}{2}\cdot\frac{\tan\phi_e - \tan\phi_f}{1 + \tan^2\phi_0}$$
$$= \frac{\cos^2\phi_0}{2}\left[-\frac{1}{\omega R_e C_e} + \frac{1}{\omega R_f C_f}\right]$$
$$= \frac{\cos^2\phi_0}{2\omega C_g^2 R_g^2}\left[-R_f C_f + R_e C_e\right]$$
$$= \frac{\cos^2\phi_0}{2\omega C_g^2 R_g^2}\left[-(R_e+\delta R)(C_e+\delta C) + R_e C_e\right]$$

Hence $\sin\mu \doteq \dfrac{\cos^2\phi_0}{2\omega C_g^2 R_g^2}\left[-\delta C.R_f - \delta R.C_e\right] \ldots(8)$

From equation (1), $\tan\theta = \dfrac{2\sqrt{M}\sin\mu}{1-M}$

$$= \frac{2\sqrt{Z_e/Z_f}\sin\mu}{1 - Z_e/Z_f}$$

$$\therefore\ Z_f - Z_e = 2\,Z_0\sin\mu\cot\theta$$

$$\doteq -2Z_0\cot\theta\,\frac{\cos^2\phi_0}{2\omega C_g^2 R_g^2}\left[\delta R.C_e + \delta C.R_f\right] \ldots\ldots(9)$$

Substituting for $Z_f - Z_e$ $(= OB - OA)$ and for AB (equation (7)), equation (6) becomes

$$\cos\theta = \pm\left[\frac{2\,Z_0\,\omega C_g^2\cot\theta}{\sqrt{\delta C^2 + \omega^2.\delta R^2.C_g^4}}\cdot\frac{\cos^2\phi_0}{2\omega C_g^2 R_g^2}\right]\times$$
$$\left[\delta R.C_e + \delta C.R_f\right]$$

$$\therefore\ \sin\theta = \pm\frac{Z_0\cos^2\phi_0}{R_g^2\sqrt{\delta C^2 + \omega^2.\delta R^2.C_g^4}}\left[\delta R.C_e + \delta C.R_f\right]$$

For small differences between Z_e and Z_f, $R_g^2\sec^2\phi_0 = Z_0^2$

Hence $\sin\theta = \pm\dfrac{1}{Z_0}\cdot\dfrac{(\delta R.C_e + \delta C.R_f)}{\sqrt{\delta C^2 + \omega^2.\delta R^2.C_g^4}}$

and $2\beta l = n\pi \pm \sin^{-1}\dfrac{1}{Z_0}\cdot\dfrac{(\delta R.C_e + \delta C.R_f)}{\sqrt{\delta C^2 + \omega^2.\delta R^2.C_g^4}}$ rads (10)

The appropriate signs of δR and δC as given by equations (3) must be employed in this formula.

Compared with equation (1) there is an extra degree of ambiguity due to the sign of the sine term. For a series of measurements at different frequencies, the quadrant in which θ lies usually becomes self-evident. In other cases, the sign of the tangent in equation (1) is often clear down to fairly small differences of Z_e and Z_f, even though the approximate formula is necessary to give the numerical value of θ. If the attenuation is also calculated, the derivation of one of the primary constants, whose order is known, will also indicate the correct quadrant for θ.

The Implementation of the New Radio Frequency Allocation Table

U.D.C. 654.1 : 621.3.029.5

Introduction.

THE International Administrative Radio Conference (Atlantic City 1947)[1] recognised that the changes made by the Conference to the bands of radio frequencies allocated for use by the various types of radio services would involve the preparation of a new and accurate list of individual stations using the various frequencies. This factual frequency list was regarded as an indispensable requirement to enable Administrations to select frequencies for new circuits and to replace those that were not in accordance with the new table, with a minimum risk of causing or suffering interference, as well as to enable the newly created International Frequency Registration Board to fulfil completely the task for which it was set up. A resolution was therefore adopted by the Conference defining the methods to be followed to prepare such a new frequency list as a prerequisite to the implementation of the new frequency allocation table.

Since the new frequency allocation table contained certain bands of frequencies set aside for the exclusive use of certain types of radio services, such as broadcasting, aeronautical mobile, and maritime mobile, and since frequencies lying between 150 and 2850 kc/s and above 27·5 Mc/s are of regional rather than global significance, the resolution visualised that the work of preparing the new frequency list would be divided amongst a number of specialised Conferences. Such specialised Conferences have been and are being held; amongst these were an aeronautical mobile conference, held in two parts in 1948 and 1949 in Geneva, a high-frequency broadcasting Conference held in Mexico City in 1948/49[2] and at present continuing in Rapallo, and Regional Conferences which were held during 1949 in respect of Regions 1 and 3 in Geneva, and for Region 2 in Washington. The geographical division of the world into the three regions for the purposes of frequency allocation is shown in Fig. 1.

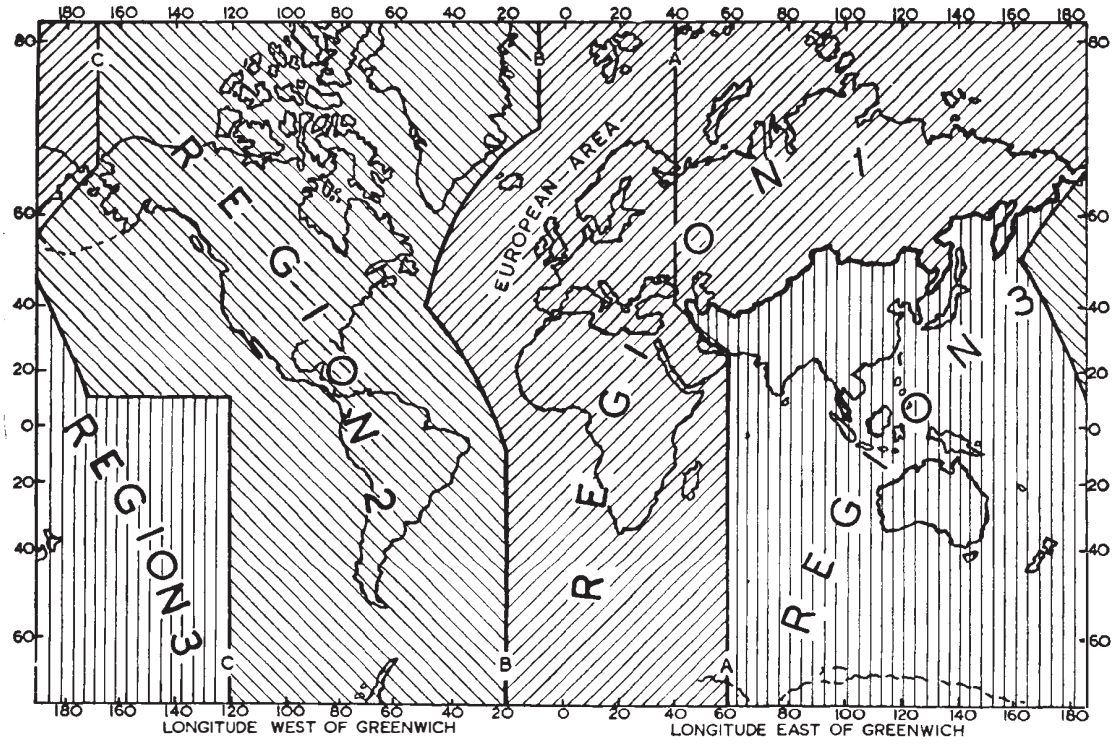


FIG. 1.—GEOGRAPHICAL DIVISION OF THE WORLD FOR FREQUENCY ALLOCATIONS.

These specialised Aeronautical and Broadcasting Conferences, however, covered only a proportion of the high-frequency spectrum and were not concerned with the fixed services which, together with tropical broadcasting and land mobile services, occupy the remaining, and greater, part of the spectrum. The fixed services form the backbone of world communication facilities both internationally, and nationally in the cases of geographically large countries. In order

[1] *P.O.E.E.J.*, Vol. 40, p. 175.
[2] *P.O.E.E.J.*, Vol. 42, p. 166.

to prepare the draft of a new frequency assignment list for these fixed services a special technical Board, known as the Provisional Frequency Board, was established and given clear but restrictive terms of reference by the Conference, and this Board functioned continuously from January 1948 until February 1950.

The Provisional Frequency Board, Geneva, 1948-1950.

The constitution of the Board, as laid down by the Atlantic City Conference, was to be the eleven members of the International Frequency Registration Board assisted by one technically expert representative of each Administration wishing to take part in the work, these latter experts being assisted by as many advisers as desired. Thus it will be seen that the Board was essentially technical, being, in fact, a preparatory technical committee set up to draft a new frequency list on a technical basis for the consideration of an Administrative Conference. This was often forgotten at plenary assemblies of the Board where national members tended to consider themselves as delegates and strayed from the technical into the political field. During the long life of the full Board there were generally present some fifty members and advisers possessing varying degrees of skill in the problem under discussion. As directed by the Atlantic City Conference, the Board convened in January 1948 and will formally dissolve at some date still in the future when a new frequency list has been accepted by a Special Administrative Radio Conference.

In the past, whenever a new radio circuit was about to be established it has generally been the practice for the design engineer to select the number and position in the spectrum of the frequencies considered necessary for the maintenance of the circuit and then to examine the current list of frequencies published by the International Telecommunications Union (I.T.U.) secretariat and select what appeared to be clear spaces in the spectrum of sufficient width to accommodate the intelligence to be carried by the circuit. As a safeguard, wherever possible, the receiving terminal of the circuit was requested to monitor the spaces selected during the appropriate times when the frequencies were likely to be used to confirm that they were in fact clear of interference. After such confirmation the frequencies would be brought into use and this fact communicated to the I.T.U. secretariat for inclusion in the subsequent publications of the frequency list. It was also the theory, but not the practice, that when an Administration ceased to use a frequency it should be deleted from the list, but since this was hardly ever done, the latest lists published contained a good deal of redundant information which seriously limited their usefulness to the operating engineers. The principal consideration influencing the reluctance of an Administration to cancel notifications in the list was undoubtedly that of losing its claim to the use of such frequencies, this claim being tacitly admitted by virtue of the publication of the use and further supported by the date published of such use against the frequency entry. Although these dates of use have no legal force, they have come to be considered as conferring some degree of priority to the use of frequencies in the case of disputes.

From the foregoing it will be clear that it was a matter of almost personal discretion how many individual frequencies were employed on any particular circuit and their disposition throughout the spectrum, and it was thought by the Atlantic City Conference that if some technical rules could be established that could be universally applied to all circuits, from which the minimum number of frequencies and the minimum band width of the emissions could be determined, it should be possible to effect a very great saving in the use of spectrum space and, at the same time, produce a new frequency list based upon sound technical principles. This, then, was the task given to the Board and it was hoped that the work could be completed within twelve months.

In the discussions at Atlantic City the United Kingdom had expected the Board to approach its task in a practical rather than an academic manner and to base its work on good engineering practice. It was, of course, recognised that many of the problems to be solved were far more appropriate to the C.C.I.R. if the best possible solutions were to be found, but the time available would not permit this course to be followed although very often the Board spent a good deal of time endeavouring to reach perfection with imperfect data.

Some idea of the magnitude of the work can be gained from the fact that about 15,000 radio circuits of all types were filed for engineering by the Board and the mere editorial work of checking, correcting and issuing lists of all these requirements occupied some six months. In the meantime, various working groups were set up to consider the various technical principles to be used, such as tolerable signal-to-interference ratios, minimum band widths required for different types of emission, and the degree of fading to be allowed for, whilst others were employed in drawing up propagation charts for various types of circuit. All this preliminary work was not completed until early in 1949 after which, of course, the principles had to be applied to the 15,000 circuits, and the frequency list drawn up. Since, on an average, a circuit requires some two or three different frequencies, the list would have to contain some 40,000 individual frequency assignments each, ideally, operating without interference.

Although the Atlantic City Conference had anticipated that the whole task of the Board could be completed by the end of 1948 the Administrative Council of the I.T.U., being aware of the delays experienced by the Board, extended its life up to May 1949 in the hope that sufficient time would be available for the completion of the technical rules and their application to all the circuits.

An examination of the current I.T.U. frequency list will disclose the fact that almost every frequency is shared by many individual stations although, on theoretical considerations, such sharing would be impossible without some of the stations experiencing intolerable interference. It must, therefore, be presumed that the sharing has been developed on a practical rather than theoretical basis, with its imperfect assumptions, and is possible either on account of the intermittent nature of the traffic on some circuits, or the provision of special means to

reduce the interference to tolerable levels, such as directive aerials or even, maybe, very slight changes of frequencies. Whatever means have been adopted there is no doubt that this existing world frequency-sharing pattern is both practical and economical. The frequency complement rules adopted by the Board, whilst being theoretically sound, within the limits of their assumptions, had the effect of entirely destroying this highly developed practical sharing pattern and must be regarded as one of the principal causes of the failure of the Board. For example, a circuit to-day might be operating quite satisfactorily with frequencies of the order of 6, 12 and 18 Mc/s, and on the 12 Mc/s frequency there might be six other stations sharing the frequency; under the new complement rules the circuit might have been given a complement of 4, 9, 15 and 21 Mc/s and it would be quite fortuitous if the six stations sharing a frequency with this circuit found themselves allocated either a 9 or 15 Mc/s frequency that would permit the same sharing pattern to be maintained.

There was also another major difficulty impeding the work, which was the complete lack of co-operation of the U.S.S.R. and certain other countries sympathetic with its political views. It had been hoped all along that these unco-operative countries would, in the end, give their valuable assistance to bring the work to a successful conclusion, but this hope was not fulfilled. When this situation became abundantly clear without the slightest doubt, the United Kingdom felt that there was no chance of a practical list being produced that could be implemented with any confidence because, if one of the greatest users of radio frequencies would not agree to conform with any new plan for the use of radio frequencies, there would exist the gravest danger of severe interference being caused to world communications. Had the U.S.S.R. co-operated, there might have been some slight chance of an acceptable list being drawn up, although it must be admitted that the great number of " requirements " filed with the Board, coupled with the generous frequency complements permitted by the technical principles adopted by the Board, tended to make this chance remote.

The United Kingdom therefore proposed formally early in 1949 that the Board should adjourn indefinitely after May of that year, since, in view of the obvious difficulties facing it, there seemed to be no chance of it completing its work, and that alternative solutions should be sought. This course, however, did not commend itself to the Board, which continued to work on and reported the situation at the next meeting of the Administrative Council which was held in August 1949. Having been told that the Board hoped to be able to complete its work within a matter of some six months, a view with which the United Kingdom member and some other members of the Council did not concur, by a majority the Council prolonged the life of the Board, by voting funds for its maintenance, until the end of February 1950.

The United Kingdom accepted this majority decision and continued to support the work of the Board until it adjourned at the end of February 1950. The results of its work were due to be examined by an Extraordinary Radio Administrative Conference to be convened at The Hague in September 1950 for this purpose.

The results of the work cannot be said to be very promising so far as their acceptance and implementation are concerned. Draft frequency assignment plans were drawn up for the maritime mobile telegraph and telephone bands at 4, 6, 8, 12, 16 and 22 Mc/s which, although not completely acceptable in their draft form, are believed to be capable of being made into a practical and acceptable form. So far as the vital fixed services are concerned, frequency assignment plans were drawn up for some frequency bands, although such plans were made only by arbitrary reductions in the number of frequencies allocated to Administrations, and arbitrary assignments made to meet the estimated requirements of the U.S.S.R. and the other unco-operative countries. In the other frequency bands the number of requirements for frequencies so greatly exceeded the number available that no attempt was made to draft an assignment plan

Throughout the life of the Board the Engineering Department maintained at least one officer, and for long periods as many as three officers, in Geneva and it is a matter of regret that the efforts of the Board have resulted in so little that is useful to the solution of this complex problem.

The Region 1 *Conference, Geneva,* 1949.

This Conference was required to assign frequencies in the bands 255 to 415 kc/s, 1605 to 2850 kc/s, 3155 to 3400 kc/s and 3500 to 3900 kc/s, bearing in mind the results of the Copenhagen Broadcasting and Maritime Radio Conferences (1948) in the band 255 to 415 kc/s.

Of the forty-five countries in the Region, thirty-six took part in the Conference, although a number of these took no effective part and gave proxies to other delegations. The Post Office members of the delegation held the leadership of the United Kingdom, United Kingdom Colonies and Southern Rhodesian delegation and were assisted by officers from the Services, Ministry of Civil Aviation, Ministry of Transport and Cable & Wireless, Ltd.

The Conference commenced its work by discussing at great length various questions such as the admission of observers and the languages to be used, many of which had a political flavour. After the first few meetings of the Plenary Assembly only French and English were used, maximum use being made of the simultaneous translation system, although in working groups consecutive translation was the rule.

The Conference divided its work among six committees, of which the chairmanship of the important Committee 6, dealing with assignments between 1605 and 3900 kc/s, fell to the United Kingdom. The other assignment committee (No. 5) had as its major problem the assignment of frequencies for maritime and aeronautical radio beacons which permitted the application of fairly rigid technical principles, but owing to the volume of requirements for fixed and mobile services in the Committee 6 bands, such an approach was never available in the same way in that committee.

As the work of the Conference progressed the sharp

split between the U.S.S.R. and its sympathiser countries on the one hand and the other countries of the Region extended to the technical plane and resulted in the so-called Eastern bloc preparing its own minority assignment plan which naturally was unacceptable to the Conference.

When all requirements had been submitted, they amounted to nearly 4,000, the bulk of which fell in the bands above 1605 kc/s, and in spite of the efforts of the working groups of Committee 6 it was impossible to satisfy all countries. The amount of dissatisfaction was noticeable when it came to the point of signing the Final Acts, at which stage every country prepared to enter reservations on the Plan. However, it became possible to dispense with the majority of these by adopting a formula whereby countries signed the Final Acts subject to their retaining the right ". . . to submit, if it should be found necessary, certain amended or additional requirements at the time of the Special Administrative Conference."[3]

The Final Acts were signed on the 17th September, 1949, after four months' work, of which the real task of writing the frequency assignment list was carried out mainly in the final six weeks.

It will be noted that the frequency bands dealt with exclude the bands 150-255 kc/s and 415-1605 kc/s which for the European area of Region 1 had been dealt with at the Copenhagen Conference in 1948. In order to rectify this omission a separate African Committee was set up to make the necessary assignments and successfully completed its task during a few days in September 1949 but with the same reservation on signature as in the Region 1 Final Acts.

[3] Now the Extraordinary Administrative Conference charged with drawing up the complete new International Frequency List.

The Region 3 Conference, Geneva, 1949.

This Conference which opened on the 18th May, 1949, concurrently with the Region 1 Conference, was required to assign frequencies in the frequency bands below 3900 kc/s, excluding 14-150 kc/s, 2850-3159 kc/s and 3400-3500 kc/s. Of the sixteen countries members of the International Telecommunications Union in the Region, fourteen took part in the Conference and the leadership of the United Kingdom Colonial delegation was held by a member of the Post Office.

The Region 3 Conference had an advantage over the Region 1 Conference in that a Preparatory Committee had met in 1948 and had prepared the ground for the Conference proper. Thus the preparatory stages of designating committees and chairmen and vice-chairmen were very quickly completed.

However, the volume of requirements in the Region proved to be some three times that of Region 1. Bearing in mind that the frequency bands considered included the medium and low frequency broadcasting bands, the problem of satisfying all requirements became even more acute than in Region 1. In particular, broadcasting requirements in the bands 2300-2498 kc/s and 3200-3400 kc/s which were of great importance to many of the countries of the Region proved to be an extremely difficult problem and held up the work of the Conference for a week or so.

As a result of these difficulties, coupled with various other subjects of a political nature which arose during the Conference, a Final Plan was not evolved until late October 1949 and signatures under the same formula as in Region 1 were not appended to the Final Acts until the 4th November, 1949.

A. H. M.

Commission Mixte Internationale (C.M.I.), Paris, 1950

U.D.C. 061.3 : 621.316.9 : 620.193.92

THE Sixth Plenary Assembly of the Commission Mixte Internationale was held at the Headquarters Building of the Administration Française des Postes, Télégraphes, et Téléphones in Paris, from 19th to 26th June, 1950. Two officers of the Post Office Engineering Department attended the Assembly as representatives of the C.C.I.F. and the British Post Office. Other organisations represented at the Assembly were :—

The Conférence Internationale des Grands Réseaux Electriques (C.I.G.R.E.),

Union Internationale des Chemins de fer (U.I.C.),

Union Internationale des Producteurs et Distributeurs d'énérgie électrique (U.N.I.P.E.D.E.),

Union Internationale de l'Industrie du Gaz (U.I.G.),

together with associated members including representatives of the Institution of Electrical Engineers, the Electrical Research Association and manufacturers of electrical apparatus in various European countries.

The C.M.I. provides an opportunity for the discussion of common problems affecting telecommunications, generation and distribution of electric power, electric transport and the distribution of gas and water. The C.M.I. has two sections, as below, which deal with the two main problems :—

First Section.—The protection of telecommunication circuits from difficulties and dangers arising from electric power and traction systems,

Second Section.—Protection of underground plant from corrosion.

There are two distinct aspects of the first problem,

(*a*) noise interference in telecommunication circuits arising from electric power and traction systems, and

(*b*) dangers due to contact between power and telecommunication systems, or due to induction at fundamental frequency.

The main item of interest under (*a*) was the revised psophometer weighting curve which had been approved at the C.C.I.F. XVth Plenary Assembly in Paris, 1949. As a result of the discussion, it was decided to recommend that the table of "weights" from which the weighting curve is derived should be extended to include figures for every 50 cycles from 50 to 3,000, and every 100 cycles from 3,000-5,000

cycles per second. It was further recommended that the admissible tolerances on these figures should be :—

50-	300 c/s	± 2 db.
300-	800 c/s	± 1 db.
	800 c/s	0 db.
800-3,000	c/s	± 1 db.
3,000-3,500	c/s	± 2 db.
3,500-5,000	c/s	± 3 db.

The question of the weighting curve and tolerances received further consideration at the meeting of the C.C.I.F. in Geneva in October, 1950.

Other matters discussed under (*a*) were the generation and flow of harmonics in power systems arising from the use of ionic convertors, e.g. mercury arc rectifiers ; the effect of electric railway systems on telecommunication lines ; the use of carrier currents on H.V. transmission lines ; and the permissible limit of induced noise in telephone circuits.

The main topic of interest to Great Britain under item (*b*) was the presentation of a full report on and the showing of the film record of some tests carried out in July, 1948, at Waresley Park in Huntingdonshire, when a live 33-kV (19 kV to earth) power conductor was dropped on to a telephone route of open wires and a small aerial cable. The film was made by the Post Office Research Station, is in colour and runs for about 10 minutes. The fall of the "dropped" power conductor was photographed in each of three tests by two cameras, one running at 500 frames per second and the other at 64 frames per second, so that when the film is shown at normal speed (16 frames per second) the actual dropping of the power conductor can be observed at about one-thirtieth and one-quarter actual speed. The most spectacular part of the film is the third test, in which the fault current was about 900 amperes and the duration of the fault (controlled at the power station) was 2·98 seconds. All the telephone wires were brought down (for the third test the aerial cable had been removed) with much arcing between the power conductor and the telephone wires, and between the telephone wires themselves.

The report presented to the Assembly contains details (not shown in the film) of the damage caused to specially erected exchange and subscribers' apparatus and lead-in cables. The cables were burst and burnt-out in each test. The lightning protectors and fuses fitted to the telephone lines suffered heavy discharges and damage, one protector unit setting fire to the wall of the wooden hut on which it was mounted. The discharge on the protectors and lead-in cables prevented appreciable damage to the telephones and switchboards which were connected to the telephone wires, but a voltage device, fitted to one of the telephones to simulate a man in the act of dialling, was found to have recorded over 1,000V. This voltage would most probably have given a fatal shock under the circumstances of the test.

The tests provided much valuable information, although in the last one the equipment measuring the voltage to earth of the telephone wires flashed over and caught fire, spoiling the last part of the record. The maximum voltage recorded was about 5,000V between the telephone wires and earth, the rest of the power voltage being dissipated in the line and the large neutral earthing resistance at the power station. The results of the tests indicate that when the existing regulations concerning the guarding and protection of telephone lines from power lines were framed they were not unreasonable. There may be a case, however, for reconsideration of the position if quick-acting circuit breakers could be assured in every circumstance.

Other matters discussed under (*b*) were induction at fundamental frequency between power and telephone lines, and the existence together of telecommunication lines and H.V. D.C. power systems. In connection with this latter item an interesting report was presented by a Swedish representative on the projected scheme for the laying of a H.V. D.C. submarine power cable between the Swedish mainland and the Island of Gotland. Fuller details of this scheme were presented subsequently at the meeting of C.I.G.R.E. held in Paris in July, 1950.

In connection with the problem of corrosion dealt with by the Second Section of the C.M.I., prior to the main Assembly in Paris, an interesting demonstration had been arranged in Brussels and Antwerp of the various methods of protecting underground pipes and cables against electrolytic corrosion caused by stray currents. The measures demonstrated included direct and polarised drainage at tramway and electric railway sub-stations, forced electric drainage using an external source of E.M.F. at points on the tramway system remote from the sub-station, and cathodic protection in areas remote from a D.C. traction system using "sacrificial" anodes or reactive anodes (magnesium billets).

The problem of corrosion, which affects equally the telecommunications, water and gas authorities, and to a smaller extent the power authorities, was discussed in all its aspects, including the statistical recording of information concerning corrosion faults; the production, flow and prevention of stray currents; the protection of cables or pipes by wrappings or armourings; the protection of cables or pipes by the use of electric or cathodic protection; the particular problem of the existence of trolley vehicle systems and their effect on stray current corrosion; the problem of corrosion arising from the use of H.V. D.C. power systems; and the study of the physico-chemical aspect of corrosion. In connection with the last item, a lecture was given by Professor Pourbaix, of the University of Brussels, in which he gave particulars of some fundamental research which he had carried out on the problem of the negative potential necessary to immunise from corrosion such metals as iron, lead and copper. The potential required was specified precisely by means of diagrams giving equilibrium potential plotted against pH value for these three metals, and showing the circumstances under which the various reactions are thermo-dynamically possible.

A full report on the Proceedings of the Sixth Plenary Assembly of the C.M.I. is to be printed and published in due course.

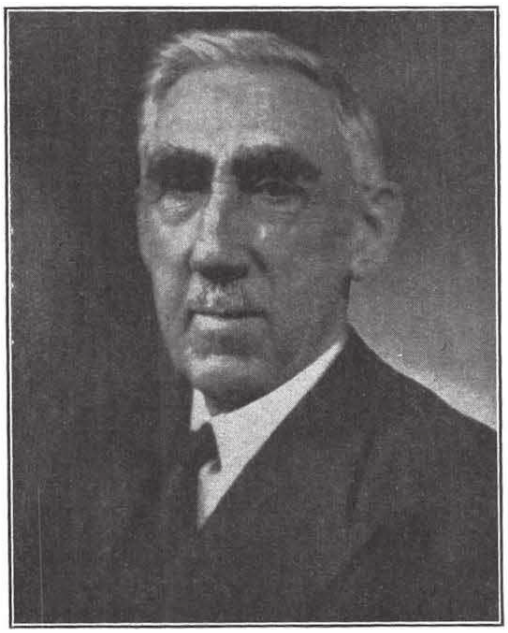
E. C. S.

Obituary

SIR FRANK GILL, K.C.M.G., O.B.E., Hon.M.I.E.E.

Frank Gill, born in 1866 in the Isle of Man, was educated at private schools and joined the United Telephone Co. in London in 1882. The Company owned many of the early master patents in this country, and Gill was in the telephone business almost from the start. His technical education seems to have followed later, chiefly by evening classes at Finsbury Technical College under Professor Ayrton, although he also studied later under such pioneers in the radio field as Lodge and Fleming. He knew Alexander Graham Bell and Oliver Heaviside.

Two years after entering the telephone service, Gill went to Ireland with the Telephone Company of Ireland. Appointed chief electrician for the Liverpool district of the National Telephone Co. in 1890, he subsequently became district manager at Blackburn, provincial manager for Ireland in Dublin, and, in 1902, Engineer-in-Chief of the Company. He held this position during an eventful period in the history of the telephone in Great Britain until the Company was taken over by the Post Office on 1st January, 1912, adding its engineering staff of about 7,000 to the 9,000 already in the Post Office Engineering Department.



For the next few years, Gill did consulting work, chiefly in South America and Europe, although during the latter part of World War I he served as Controller in the Central Stores Department of the Ministry of Munitions. In 1919, however, he became European Chief Engineer of the International Western Electric Co. (later the International Standard Electric Corporation). During the years that followed, he was responsible for the reconstruction of the Spanish telephone system and for the building of an up-to-date system in China for the Shanghai Telephone Co. At the time of his death, he was Chairman of Standard Telephones & Cables, Ltd., the International Marine Radio Co., Ltd., Standard Telecommunication Laboratories, Ltd., and Creed & Co., Ltd.; he was also a Vice-President of the International Standard Electric Corporation. Despite his great commercial and technical responsibilities, he retained a great interest in the younger generation of engineers to whom he was always accessible.

In 1922, Gill was elected President of the Institution of Electrical Engineers. In his inaugural address, he suggested a body to do for long-distance telephony in Europe all that no one nation could do alone. His suggestion led to the formation, two years later, of the Comité Consultatif International Téléphonique (C.C.I.F.), which has not only promoted international telephony but, during the last quarter of a century, has done much to co-ordinate technical development in Europe It is fitting that he should have died, in harness, while attending a meeting of the C.C.I.F. in Geneva.

Elected as Honorary Member of the Institution of Electrical Engineers in 1938, he was also a Member of the Institution of Civil Engineers, a Fellow of the American Institute of Electrical Engineers, Honorary Member of the Institute of Royal Engineers, and a member of the Royal Institution, the Société des Ingenieurs Civil de France and the Société Française des Electriciens.

He was made K.C.M.G. in 1941 for his services to international telephony and was awarded honours by the Spanish and Chinese Governments for his assistance to these countries as a telephone engineer. His interests, however, extended beyond the limits of telecommunication and found expression in a variety of activities prompted by his faith in the doctrines of Christianity. The practical idealism of the man was revealed in the closing sentences of his Presidential address to the I.E.E.—"If only we will use it (international telephony), we shall be making a definite step towards reducing international jealousies and fears, and increasing the goodwill without which there cannot be peace on earth."

The crowded congregation at the Memorial Services in the King's Chapel, of the Savoy in London, and the service in the English Church at Geneva, attended by the C.C.I.F. as a body, were tributes, not only to one of the outstanding telephone engineers of the first half of the century but also to the personal esteem in which he was held.

W. G. R.

Notes and Comments

Recent Awards

The Board of Editors has learnt with great pleasure of the honours recently conferred upon the following members of the Engineering Department :—

London Telecomms. Region	Burch, L. J.	Technician, Class I	Sergeant, Royal Signals	Mentioned in Despatches
London Telecomms. Region	Garrad, R. C.	Technical Officer	Sergeant, Royal Signals	British Empire Medal and Mentioned in Despatches

Mr. R. J. Hines, B.Sc., M.I.E.E.

Mr. Hines was born in 1902 and many will remember his father, Capt. J. G. Hines, Staff Engineer of the Lines Branch at the time of his retirement in 1937.

Receiving his training at Royal School and King's College, London, Mr. Hines commenced his career with Messrs. Siemens Bros., and there gained experience in the design of automatic telephone circuits.

Entering the London Engineering District as a U.S.W., he was shortly successful in the competitive examination for acting Inspector. With this appointment, he became one of those known as the "forty thieves," many of whom now occupy senior posts in the Department.

After two years on cable-testing, and being successful in the open competition for Assistant Engineer (old style), he was appointed to the automatic training school at King Edward Building.

Self-confessed "Jack of All Trades" rather than a specialist, and always more interested in the

managerial aspects as against the narrower technical field, Mr. Hines secured early transfer to Colchester and thence, on promotion, to Sectional Engineer at Bournemouth.

Less than four years later, promotion to Regional Engineer brought the commencement of a period of nearly 14 years in the North-Eastern Region.

In 1942 he accepted a commission in the Royal Signals. Having planned many emergency schemes in this country, he was admirably fitted to tackle the problem of replanning communications on the Continent, first as a Civil Affairs Officer in Belgium and Holland, and later as a Lt.-Col. in the American-occupied part of Bremen, where he says that the letters C.C.G. were more aptly interpreted as "complete chaos in Germany."

Returning to Leeds in 1945, he again took charge of the Internal group in the Regional Office, well content again to take up the threads of life in a city he appeared to find so congenial.

He now goes "north of the border" as Chief Regional Engineer of the Scottish Region.

W. F. S.

Heaviside Centenary Volume

Many readers will be interested to know that a "Heaviside Centenary Volume" has recently been published containing the authoritative papers read, and the tributes paid by eminent scientists, on the occasion of the Centenary Celebrations as described in our last issue.

Copies of this publication can be obtained on application to The Secretary, The Institution of Electrical Engineers, Savoy Place, London, W.C.2, the price being 4s. to members of the I.E.E. and 10s. to non-members.

Welcome to New Readers

Special steps have been taken recently to bring to the notice of junior engineering staff the advantages to be obtained by reading the Journal, and the initial response has proved most encouraging.

This opportunity is taken, therefore, to extend a warm welcome to the new subscribers, numbering more than 1,000, and to ensure them of our intentions to continue to include in each issue of the Journal as wide a range of articles as possible so as to cater for all interests.

Elsewhere in this issue will be found reports from Local Centres of the Institution's Junior Section—a regular feature designed to publicise this important part of the Institution's activities. It is hoped that junior readers not yet taking advantage of the valuable facilities available from membership of the Junior Section will study this section of the Journal and be encouraged to join in the local activities.

Sir Archibald Gill's I.E.E. Presidential Address

As most of our readers are now aware, Sir Archibald J. Gill, B.Sc.(Eng.), M.I.E.E., F.I.R.E., Engineer-in-Chief of the Post Office, has been elected as President of the Institution of Electrical Engineers for the session 1950-51. This latest distinction, the highest honour in the electrical engineering profession, has been noted with pleasure by the members of his Department and by his many friends and associates in the sphere of telecommunications.

For his Inaugural Address, delivered before a crowded Institution on 5th October, 1950, the new President took as his subject the more recent developments in telecommunications in this country, and in particular those concerning the telephone service.

Dealing first with local-line cables, representing about 40 per cent. of the total capital cost of the telephone service, he referred to the close study at home and abroad of methods by which cheaper construction costs could be obtained. Thus, in this country during recent years, a system of distribution, using street cabinets and pillars, had been introduced, giving cross-connection facilities which obviated the necessity for frequent opening and rearrangements at cable joints. Other economies had arisen from the introduction of shared service in which two subscribers share a single exchange line with individual calling facilities and, in many instances, individual metering. Quoting the reasons why it was preferable that shared service should be non-private, Sir Archibald intimated that the system appeared to be quite popular with the 230,000 subscribers now connected in this manner.

Turning next to the subject of switching, some account was given regarding the present extent of the conversion from manual to automatic working, the stations now served by automatic exchanges representing 70 per cent. of the total as against only 25 per cent. in 1929. In recent years, the conversion policy had been steadily applied to small caretaker-operated rural exchanges, many of which were housed in private premises ; in emergencies, such as the removal of a caretaker at short notice, service could be maintained, pending conversion, by the use of the mobile automatic exchanges now available.

Referring to recent visits by experts from this country to all parts of the world to examine progress in telephone development, Sir Archibald emphasised that nothing had been seen to suggest that the step-by-step system was obsolete or even obsolescent. In paying tribute to the late Sir Thomas Purves for the wisdom of his decision 25 years earlier to standardise on the Strowger system, he said that the system continued to fulfil every demand made upon it since this type of equipment could be simply applied to the largest and smallest of exchanges. He mentioned, however, the possibility that something entirely novel might appear in the future, as, for example, an electronic system ; in this connection, the Post Office had already designed and tested a two-digit electronic director, examples of which would shortly be on field trial. Subject to the production of long-life valves—and it was pointed out that this possibility no longer appeared remote—a fully electronic system with its high operating speeds and elimination of moving contacts opened up great possibilities.

The address continued with a survey of recent signalling developments and, in particular, their bearing on the present objective of a mechanised inland trunk network. Sir Archibald explained that when this network was completed a controlling operator at any trunk centre would be able to complete a call to any subscriber on an automatic exchange without the assistance of a second operator. The resultant extension of tandem dialling would fundamentally change the requirements of manual switchboards in that the need for an outgoing manual multiple would be removed ; under these conditions the cord-type board would be replaced by a cordless board with key-controlled connecting circuits, and much improved working conditions would result for operators. An indication was also given that the mechanisation of trunk switching, with its immediate objective of a saving in operators, had been engineered so as not to prejudice unduly the possible long-term project of a scheme of subscriber-to-subscriber dialling with national numbering.

Because the most rapid advances in recent years have been concerned with transmission, this subject was dealt with at some length, and, after stressing the fundamental importance of the negative-feedback amplifier in carrier working, Sir Archibald detailed the main features of the various carrier and coaxial systems now in use in this country. He pointed out that a disadvantage of the coaxial system was that circuits could not readily be taken off at intermediate points on the cable, but against this the cost per channel was less than for multi-pair carrier working and, in addition, the coaxial system could be used for the transmission of television signals. As a result, most new long-distance trunk cables laid in recent years had been of the coaxial type. Special mention was made of the new London-Birmingham coaxial cable, of composite construction, which includes two 0·975-in. tubes for a television circuit between London and Birmingham alternative to the V.H.F. chain now in operation.

A matter of particular interest, which was enlarged upon, concerned the provision of television circuits for outside broadcasts. Although special cables had been laid in the London area to serve selected points, circuits also had to be provided, often at short notice, to locations at some distance from the nearest point of access to the special network. On such occasions the circuit was completed by the use of ordinary pairs in the local telephone distribution cables which normally carried only audio frequencies. Such circuits had to be connected through adjustable equaliser and amplifier equipment, and were lined-up by transmitting pulses of 20 microsec. length, the received pulse shape being examined on an oscillograph at the distant end and adjustments made as necessary.

Details of the progress on submarine cables were of special interest in that many of the audience had recently visited the exhibition at the Science Museum organised by the Post Office to celebrate the centenary of the laying of the first submarine cable across the Straits of Dover. The most notable advances had

occurred in the introduction of carrier working as for land cables, the striking increase in circuit capacity being evidenced by the latest Anglo-Belgian coaxial cable (using polythene insulant) in which capacity for 216 circuits is available. It was revealed that, during the period under review, considerable progress had been made in the design and construction of the submerged amplifier, a device which made possible great economies in circuit provision. On the two cables now provided with these amplifiers, very satisfactory results were being obtained.

To conclude his review, Sir Archibald dealt briefly with the overseas and internal radio services, a subject with which he has been intimately concerned for many years and on which he is a leading authority of international repute. He referred to the continued expansion of the overseas services which had been effected in spite of serious equipment shortages and accommodation difficulties, explaining that much of the progress had been made possible by the policy of converting from double-sideband to single-sideband multi-channel working. To cater for the continued growth in overseas traffic, the engineering terminal (recently transferred to Hendon) was equipped for a total of 48 overseas circuits.

The most recent development in the internal radio service is the current provision of radio chains as part of the country-wide system for the distribution of television programmes. Sir Archibald explained that the existing London-Birmingham chain would be followed by a second chain between Manchester and Edinburgh, and that with two different types of coaxial cable for television working (i.e., the London-Birmingham cable and that projected for Birmingham-Manchester) the performance of the alternative systems would provide valuable data for the future.

To illustrate that section of the address relating to television circuits and equipment, two most interesting demonstrations were staged. The first was the equalisation, by the pulse method previously mentioned, of an ordinary two-wire telephone circuit from Gerrard exchange to the Institution building.

This demonstration was a preliminary to a second demonstration—the transmission of a television programme from the Alexandra Palace studio of the B.B.C., firstly, direct to the Institution building and, secondly, from Alexandra Palace to Birmingham and back to the Institution building over the new large diameter coaxial cable. It was possible to observe that the picture had suffered no distinguishable degradation in its transmission over the second path of over 250 miles.

Finally, the two pictures were superposed to demonstrate the time of transmission which amounted to about 1/700 sec. (1·4 mS) and resulted in the two pictures being displaced 14 lines. The corresponding velocity of transmission was about 170,000 miles per sec.

The belief was expressed that in this demonstration the longest line transmission of television over cable in Europe had been effected, and the longest transmission in the world, over a cable, considering the bandwidth employed and picture quality achieved.

It had not been possible during the address to cover the whole of the developments in public telecommunications services in this country, but the hope was expressed that matters omitted or curtailed, such as the important advances in telegraphy, would be brought to the notice of the Institution in future papers.

Readers will appreciate that this very brief summary gives only the barest outline of the Presidential Address, but arrangements have been made for its publication in the I.E.E. Journal and an opportunity will thus be available to read in greater detail of the striking advances in this country's telecommunications during the past few years.

Institution of Post Office Electrical Engineers

ANNUAL AWARDS FOR JUNIOR SECTION PAPERS —SESSION 1949-50

The Judging Committee has selected the following from the papers submitted by the Local Centre Committees, and awards of £3 3s. 0d. and Institution Certificates have been made accordingly.

Author	*Junior Centre*	*Title of Paper*
K. T. Stephens	Southampton	"Radio Interference"
W. N. Pallier	York	"The Telegraph Auto. Switching System"
G. E. C. Cochrane	London	"Precision Testing"

Normally five awards are made, but in view of the comparatively small number of papers submitted on this occasion, the Council decided to limit the awards to three.

The Council is indebted to Messrs. A. C. Warren, M. C. Cooper and F. B. Wilcher for kindly undertaking the adjudication of the papers forwarded for consideration.

J. READING,
Secretary.

London Centre

The attendances at meetings of the London Centre for the first half of the current Session have compared favourably with previous years, and there is no doubt that interest will be sustained by future papers to be presented this Session as follows :—

ORDINARY MEETINGS

6th February.—"Some Aspects of Electronic Circuit Design," S. W. Broadhurst and A. W. M. Coombes, Ph.D.

6th March.—"The Provision and Maintenance of Long-Distance Circuits, London Trunk Transmission Control." E. H. Jeynes, A.M.I.E.E., and J. E. Isherwood.

8th May.—"Trunk Mechanisation." J. H. Broadhurst, A.M.I.E.E., and A. J. Thompson.

INFORMAL MEETINGS

24th January.—"ENG Service." C. Feather (N.E. Region).

21st February.—"The Art of Public Speaking." A. K. Robinson, A.M.I.E.E.

21st March.—"The 2,000-type Selector and its Problems." J. O. Thompson, B.Sc., A.M.I.E.E., and F. Haythornethwaite.

18th April.—"Training for Management." D. G. Dafforn, B.Sc., A.M.I.E.E. (C.T.S.).

The Committee would be glad to receive offers of papers from prospective authors for next Session or, alternatively, suggested subjects for papers.

It was the pre-war practice to include in printed papers a record of the relevant discussion and it would assist towards a resumption of this practice if contributors to a discussion would furnish the Local Secretary with a written record of their remarks. W. H. F.

Recent Additions to the Library

1936 *Machines that Think (or Giant Brains).* E. C. Berkeley (Amer. 1949).
Describes several large-scale mechanical computers and sets these "Mechanical Brains" in perspective by comparison with the human brain and various languages.

570A *Scientific Management.* F. W. Taylor (Amer. 1949).
Collects in one volume "Shop Management," "Principles of Scientific Management," and "Taylor's Testimony before the Special House of Representatives Committee."

1937 *Magnetism.* D. Shoenberg (Brit. 1949).
Explains as simply as possible what magnetism really is, and how it is used in many ways which affect everyday lives.

1938 *Applied Mechanics.* A. Morley (Brit. 1943).
Covers the ground of the third and final year of a three-year, part-time course of instruction leading to an Ordinary National Certificate in Mechanical Engineering.

1939 *Radio Communication at U.H.F.* J. Thomson (Brit. 1950).
Aims at providing an account of modern developments in telecommunications employing radio waves of lengths ranging from a few metres to a few millimetres.

1940 *The Electrolytic Capacitor.* A. M. Georgiev (Amer. 1945).
Describes the construction, manufacture, function and testing of dry and wet electrolytic capacitors, explains the operating characteristics of the various types, and indicates both their useful applications and their limitations.

1941 *Glued Laminated Timber Structures.* R. T. Walters (Brit. 1950).
A Timber Development Association's Constructional Research Bulletin.

1942 *Timber Pests.* Timber Development Association (Brit. 1945).
Shows how to avoid decay by the proper use of timber.

1943 *Timber Preservation.* Timber Development Association (Brit. 1949).
Gives concise information on the types of preservatives available and their methods of application.

1944 *The Making of Scientific Management.* L. Urwick and E. F. L. Brech, Vol. I—Thirteen Pioneers (Brit. 1949).
Describes the parts played by the pioneers of the scientific approach to management.

1945 *Vol. II—Management in British Industry* (Brit. 1946).
An interpretation of the part played by management in British economic history.

1946 *Electric Circuits and Fields.* H. Pender and S. R. Warren (Amer. 1943).
Describes the more important effects commonly described as electric and magnetic phenomena ; the fundamental principles in accordance with which these phenomena are related ; and their application to some of the simpler problems that arise in connection with the generation, transmission and utilisation of electric energy.

1947 *Super-Regenerative Receivers.* J. R. Whitehead (Brit. 1950).
Introduces the whole subject of super-regenerative receivers in the light of advances made in wartime radar.

1948 *Transformers.* E. E. Wild (Brit. 1948).
Covers briefly the theory, design and operation of transformers.

1949 *Sound Reproduction.* G. A. Briggs (Brit. 1950).
Gives in non-technical terms, a general outline of the technique of sound reproduction under domestic conditions.

1950 *Cold-Cathode Fluorescent Lighting.* H. A. Miller (Brit. 1949).
Describes the principles, manufacture, operation and installation of cold-cathode fluorescent lighting.

1951 *Electronics in the Factory.* H. F. Trewman (Brit. 1949).
Provides a fairly wide survey of the fields in which electronics have been successfully applied in aid of industry to improve the quality and quantity of its output.

1952 *The Theory and Design of Inductance Coils.* V. G. Welsby (Brit. 1950).†

1953 *Progressive Mathematics.* P. Clyne (Brit. 1950).*

1954 *The Theory of Machines.* T. Bevan (Brit. 1943).
Designed mainly for students preparing for a University degree in engineering, or for membership of one of the Engineering Institutions ; but many sections will appeal to the draughtsman and designer.

1955 *An Introduction to the Gas Turbine.* D. G. Shepherd (Brit. 1949).
This book aims at filling a gap between the largely descriptive matter for the general reader and the technical reports and papers for the specialist.

1956 *Inventions, Patents and Monopoly.* P. Meinhardt (Brit. 1950).
Presents a concise description of British Patent Law and Practice under the 1949 Act.

460 *Theory of Structures.* A. Morley (Brit. 1948).
In this fifth edition new diagrams have been made, and several sections of the book have been rewritten.

W. D. FLORENCE, *Librarian.*

* Reviewed on p. 197 of this issue.
† Reviewed on p. 218 of this issue.

Regional Notes

South Western Region

COMMUNICATIONS FOR THE TRADE AND TARIFF CONFERENCE, TORQUAY, 1950

In late 1949 it became apparent that advance planning was imperative if adequate telecommunications were to be provided in time for the opening of the Conference in September of the following year. A list of hotels to be taken over was obtained, therefore, and an estimate of the telephones prepared, based roughly on the number of rooms per hotel and bearing in mind other facilities, such as main conference rooms, committee rooms and so on. A large measure of flexibility was introduced by the provision of three cross-connection cabinets and the use of the M.D.F. at the Conference P.B.X. located in the Princes Hotel. The cabinets were sited also to cater for future local line requirements.

The line plant proposals necessitated additional underground duct and manholes, comprising 3,060 yards of duct, 8 manholes and 54 jointing chambers, provision being completed in August 1950, by contract and direct P.O. labour.

Following completion of the main tracks and leads to the hotels, 4·3 miles of cable, of sizes from 30 to 1,000 pair, was pulled in and jointed by the Area staff, assisted by loans of jointers from the Bournemouth and Southampton Telephone Managers' Areas.

At the outset, it was visualised that, in view of the size of the Conference, some 42 countries being represented, a central Conference P.B.X. should be constructed. Consequently, at the hotel chosen for the Secretariat, a P.M.B.X. 1A of 12 positions was installed to give an ultimate extension multiple of 500 and a 100 exchange line multiple, a special feature of the extension multiple being an ancillary lamp jack provided for a proportion of the extension multiple. These ancillary lamp jacks were left unlamped, but in the event of a variation in traffic loading per position being required the lamps could be removed from the home positions and placed in the ancillary-lamped positions. The work involved on the Conference P.B.X. required the running of 2,000 yards of switchboard cable and the termination of 36,000 wires.

At the Torquay auto exchange, an idea of the additional engineering work can be gathered from the following :—

(*a*) Provision of 60 additional circuits in the O.G.J. multiple of the auto-manual board.

(*b*) Fitting of a P.B.X. final selector rack, equipped with 20 final selectors, 11 and over, cabled and tested for the 20 outgoing lines to the Conference P.B.X., together with the fitting of additional group selectors and re-grading of two groups to cater for increase in traffic.

(*c*) Provision of 30 O.G. junction dial relay sets and 34 impulse suppression equipments for the provision of V.F. dialling circuits to London; the changing of all the dials on the manual board.

In readiness for the increased traffic to London, the London trunk circuits were augmented from 14 O.G., 10 B.W., and 12 I.C., generator signalling circuits to 34 O.G. V.F. dialling, 10 B.W., and 32 I.C. generator signalling circuits. The conversion to V.F. dialling was something entirely new to the Area staff, and some brief mention of the arrangements made with the concurrence and assistance of the Engineer-in-Chief's Office will not be out of place.

A non-standard signalling system was employed, using a separate V.F. telegraph channel for the dialling path, the V.F. signals being rectified at the distant end, and thus able to operate selectors in the London trunk network. To provide these facilities, a mobile V.F. unit was located adjacent to the repeater station at Shiphay Collaton, thus giving access to the carrier network used for the V.F. systems. Three 12-channel V.F. systems were housed in the mobile unit, and the separate V.F. signalling channels were cabled via special conversion units to the phantom circuit of the 4-wire speech path between Shiphay Collaton and Torquay.

Besides housing the 12-channel V.F. equipments, the mobile unit also contained amplifiers for the 4-wire line circuits, together with the necessary power plant. The main power supply for the V.F. equipment was arranged by running an external lead from the repeater station, cabled via a change-over switch, so that in the event of a mains failure a standby 6-kW petrol engine set could be switched in as required.

To meet telegraph requirements an 8-channel V.F. equipment, consisting of two 4-channel bays of outstation equipment, was installed at Torquay repeater station to provide additional circuits to London for the duration of the Conference and three additional teleprinter positions were provided in the Torquay H.P.O. telegraph instrument room.

Thanks to the assistance given by the hotel proprietors it was found possible to block-wire the hotels while the summer holiday guests were still in residence and in all, 24 hotels were block-wired prior to the taking over by the various delegations and some 1,250 telephones fitted.

That the installation work was completed to time was a credit to all concerned, and praise from the delegates and tributes over the wireless and in the Press have amply justified the remark that the work had been well done.

J. E. M.

ILFRACOMBE CONVERSION—MAGNETO TO C.B.10

At Ilfracombe one more of the steadily diminishing number of magneto exchanges in the country was taken out of service. A transfer from magneto to C.B. may leave something to be desired when the automatisation of the country is the ultimate goal, but in this case the H.P.O. which housed the old magneto exchange did not have suitable accommodation for an automatic exchange and the possibility of the early provision of a new building seemed unlikely. A C.B. exchange could be provided at the H.P.O., however, after some necessary floor strengthening and structural alterations had been carried out, and it was decided to go ahead and provide a C.B.10 exchange with 1,200 subscribers' calling equipments and a multiple of similar size spread over six A sections, with one B board and the usual T. and P.U. section.

A feature of interest was the method used to supplant the existing M.D.F. Development requirements called for 26 verticals under the new conditions; 12 only could be provided at the outset as the old main frame had to remain *in situ* and occupied most of the space needed for the complete new frame. The 12 new verticals were erected, two 800 pair cables brought from the basement to the main frame (which is situated on the second floor) and working pairs were diverted to these new verticals so freeing the line side of the old frame whilst leaving the multiple side of the old frame connected to the switchboard. Connection between the two frames was carried out by means of switchboard cable (plastic type mainly). The old frame was then shifted bodily out of the way and the new frame extended to its 26 verticals. Another 800 pair cable, plus the usual junction cables, were next provided and terminated

over the length of the frame. This re-distribution of all working pairs was carried out with remarkably little interference to subscribers, and tribute is due to the manner in which the staff performed this by no means straightforward operation. The two main frames being close together obviated the need for changeover strips and a lot of rather tedious terminating was thus avoided.

Most of the 80 wire switchboard cable used was of the plastic type. This type of cable tends to "flow" and needs close and careful stitching on flat runs. On vertical runs there was difficulty in keeping it in position, but after two or three re-ties it has "anchored" in its intended position.

With reasonable care terminations on plastic cable are no more difficult than with the textile type and the insulation showed no tendency to run back.

To an "old magneto man" there is something forlorn about the recovered magneto sections standing lonely and deserted alongside the smart and efficient C.B. successor, now a centre of activity. R. E. K.

North Eastern Region

WHITLEY BAY AUTOMATIC EXCHANGE

A further step towards the complete automatisation of the Newcastle-on-Tyne Telephone Area was achieved on 11th October, 1950, when Whitley Bay N.D. automatic exchange was brought into service. The new equipment replaces a CB.10 system installed in 1925 in the Whitley Bay Post Office, and also a relief exchange accommodated in the new automatic exchange building, Norham Road, and brought into service in 1947. The new building was commenced in 1939, but the incidence of hostilities suspended operations and it was not until 1947 that completion was sufficiently far advanced to commence the installation of the automatic equipment.

The automatic exchange, which was installed by the G.E.C., is a remote N.D. type, parented on Newcastle. Equipment for 6,000 subscribers has been provided, with facilities for direct access to Newcastle and associated common-charge satellite exchanges. Tandem dialling facilities are also provided for U.A.X.s with direct routes to Whitley Bay.

The transfer involved 3,663 subscribers and 176 junctions, and is the largest undertaken in the Newcastle Telephone Area since the conversion of Newcastle multi-office area in 1931. Although two manual exchanges in separate buildings were being displaced simultaneously, the almost faultless conversion which was accomplished reflects great credit on the staffs of all divisions, who showed great enthusiasm to achieve this objective.

A formal opening ceremony took place on Friday, 13th October, and included among the guests were Miss Irene Ward, M.P. for the constituency, the chairman of the Whitley Bay U.D.C., and several local dignitaries. Mr. W. F. Smith, Chief Regional Engineer, was also present on behalf of the Regional Director, N.E.R.

After a tour of the new exchange, the guests, together with a number of the local staff, were entertained to tea arranged by the Postmaster, Whitley Bay. T. P. P.

INTRODUCTION OF MULTI-METERING FACILITIES AT LEEDS EXCHANGE

In October, 1946, authority was given for the Region to proceed with the installation of multi-metering equipment at Leeds main exchange to enable automatic metering of calls of one to four unit fees when dialled by subscribers to exchanges in the 15-mile circle. A saving of 11 toll positions at 1948 was then envisaged, but the saving at present is estimated to be between 15 and 20 positions, due to the automatic completion of from 7,000 to 9,000 calls daily. The scheme has also considerably enlarged the extent of the tandem dialling facilities between exchanges in the 15-mile circle. It has not been extended to cover subscribers on satellite exchanges due, mainly, to the age of the equipment, but as the Leeds automatic area is to be converted to director working it will be possible to give the director exchange subscribers dialling access to the 15-mile circle as conversion proceeds.

The equipment has been manufactured and installed by the Automatic Telephone & Electric Co., Ltd., and, for the multi-metering portion, 538 relay sets and 958 selectors with associated banks and racks were supplied.

The scheme is the first of its kind, using level multi-metering on a large scale, and it was introduced on the 29th October, 1950, when over 10,000 subscribers at the main exchange were given direct dialling access to 46 exchanges (manual or automatic).

The codes have been arranged on the second and third selector levels trunked from level 8, and the multi-metering relay sets with regenerators have been placed between the second and third selectors.

The change-over was complicated by the fact that a tandem dialling scheme for U.A.X.s and operators was already in existence on level 8 giving dialling access to 21 exchanges. To enable these exchanges to be re-arranged in fee order on various levels, and to enable the metering strappings to be re-arranged to agree at the U.A.X.s, level 8 of the U.A.X. group was intercepted five weeks before the transfer and diverted to the auto-manual board. All-calls via this level were completed and ticketed by the operators who were provided with additional circuits to first selectors to give them access to revised codes on the levels concerned. In the case of the dialling-in exchanges, it was sufficient to withdraw access to level 8 for one week-end during which time the calls were routed (by instruction) via level "0," in order that the existing codes could be re-arranged at the main exchange.

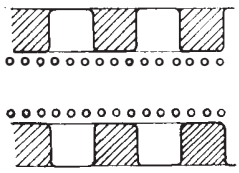
The subscribers on the main exchange were issued with directories in which a separate dialling list had been inserted, giving the code for each of the exchanges to which dialling is allowed. If a satellite subscriber dials one of the codes above unit fee, he receives "number unobtainable" tone.

The whole transfer was successfully completed as a result of the excellent co-operation between the Contractors and the Department. F. E. P.

UNUSUAL TELEVISION INTERFERENCE IN LEEDS AREA

An unusual type of television interference was recently investigated in the Leeds area and a brief account may be of interest.

The interference, which occurred only during hours of darkness, consisted of four lines horizontally across the screen, with pattern as illustrated. Although the four lines were stationary the dots under and over the lines travelled rapidly from left to right.



PATTERN FORMED ON TELEVISION SCREEN BY INTERFERENCE FROM FAULTY ELECTRIC LAMP.

Listening on the official locator (W.T.12) with the complainant's aerial in circuit revealed no interference whatever on either the sound or vision channels. On

detuning from 61·75 Mc/s to 60·50 Mc/s, a very faint hum was heard but, using the normal vertical antenna on the locator, no interference could be heard on any frequency. Touring the district in the van proved fruitless. On foot, however, the hum on 60·50 Mc/s was again picked up at a considerable distance from the complainant's premises, but it had to be proved that the hum heard and the lines seen were due to the same cause. The hum was found to be due to a defective filament in an ordinary 60-watt bulb, but the lines still persisted when the lamp was replaced.

Further investigations proved a hum peaking at a transformer station. The Yorkshire Electricity Board was called in, and momentarily flashed each section; the section with the fault was thus found, reducing the line of investigation to about 200 houses. The line of the television beam suggested the source to be in line with Sutton Coldfield, but owing to misleading intensities of interference received, due to mains-borne and direct radiation, difficulty was found in being sure of the source which finally proved to be at a point some 50 yards behind the aerial. Another lamp? Yes!

The interference arose from a badly soldered contact between the filament and the bayonet cap. Replacing this gave entire satisfaction to the complainant and, considering the distance from Sutton Coldfield, the picture received was excellent.

J. V. D.

Midland Region

FIRE AT NARBOROUGH U.A.X. 7

A fire occurred at Narborough U.A.X. 7 at midnight on 7th August, 1950. A nearby resident observed smoke coming from the building and immediately attempted to call the Leicester Fire Brigade from a kiosk. This, however, was unusable. The resident then went to the local railway station and gave the alarm over the British Railways network. The Brigade arrived at 1·58 a.m. (8th August) and had the fire under control shortly afterwards. There is little doubt that the prompt action and initiative of the local resident saved the exchange from complete destruction.

An examination of the exchange was immediately carried out. It was found that one B-unit had been completely destroyed, adjacent units scorched, and switches in the remaining units "gummed up" by the heat and smoke. Damage to the building was confined to the ceiling and roof timbers. On completion of the survey of the damage, it was decided that there was a reasonable prospect of restoring service on the existing equipment by dispensing with secondary working. As a precaution, however, it was considered advisable to obtain a mobile U.A.X. and install it ready for service if necessary. This work was completed within 24 hours. Meanwhile, service had been given to thirteen priority subscribers working on a trunk subscribers' basis to Leicester exchange. Concurrently, staff was employed cleaning and renovating switches ready for service and rewiring to cut out secondary working. During the morning of 9th August, service was restored to all emergency subscribers via the normal exchange equipment. The remaining subscribers were given service as equipment became ready for service, and full service was restored by 9 a.m. on 10th August. It is fitting to record the prompt attention and valuable assistance on the part of Headquarters, Regional and Area staff, whose untiring efforts resulted in the speedy restoration of service to some 300 subscribers.

E. S. L.

Home Counties Region

CABLE EMBEDDED IN TREE

The associated photograph shows the trunk of an elderberry tree that has grown around a portion of cable P.C.T.D. 15 10 protected.

This cable formed part of about 300 yards of buried cable serving a D.P. in Westgate-on-Sea, Kent. The route

15-PR. PROTECTED CABLE EMBEDDED IN TREE.

passed through gardens and allotments, and one portion was along a hedge. In the past five years or so, several faults developed due to the operations of gardeners, and recently faults developed close to the elderberry tree. It was then seen that the cable was completely embedded in the tree and, although no faults had developed due to this cause, the opportunity was taken to re-route the cable and recover the buried section by the hedge.

R. S. V. P.

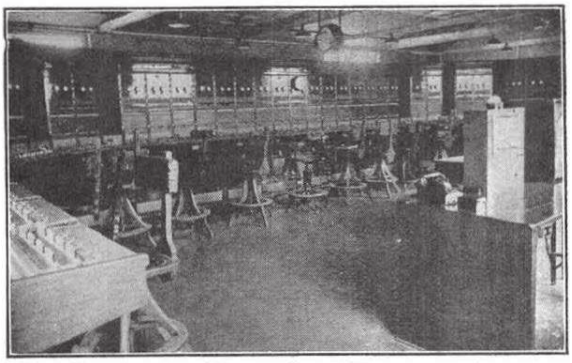
THE ROYAL SHOW, OXFORD, 1950

In 1950 the Royal Society of England's annual show revisited its birthplace, but, whereas the first of the Society's shows was held in 1839 on a site occupying seven acres, the recent show occupied 170 acres and had to be accommodated on the Oxford airport, eight miles from the City centre.

The demands for telephone service at these shows had increased in recent years, and a new peak was anticipated and, in fact, realised this year. It was decided that, despite the local arrears of telephone provision, the international importance of the show justified the work involved in meeting all the exhibitors' telephone requirements. These were estimated to be approximately 280 exchange lines and a high calling rate was anticipated. This forecast was nearly achieved, as 232 D.E.L.s for exhibitors were provided with 14 other lines and 32 kiosks. P.B.X.s were provided for the show authorities and the caterer.

No adjacent exchange was found to have a sufficient margin of spare plant to handle the temporary load, and the Oxford exchange was already fully loaded. It was decided, therefore, to open an independent C.B. No. 10 exchange on the showground and to give the exchange temporary Group Centre status so that the considerable trunk and junction traffic could be expeditiously handled. A 22-position board with six monitorial positions was built in a wooden sectional building provided by the show authorities. This board was equipped with a 400-line subscribers' multiple and an 80-line outgoing junction multiple.

A general view of the switchroom is shown in the photograph.



THE SWITCHROOM, ROYAL SHOW EXCHANGE, OXFORD.

A considerable number of trunks and junctions were required, and an advance portion of an Oxford-Charlbury C.J. cable was intercepted and led into the showground to provide 104 circuits to the Oxford repeater station, from which 4-wire circuits were provided to London, Birmingham, Bristol, etc. An M.U. cable was also intercepted to provide circuits to Woodstock and Banbury.

The problem of providing a reliable, efficient, inexpensive and yet unobstructive distribution on the showground was a difficult one, in view of the need to economise in manpower, avoid wastage of cable and yet give a service which would meet all contingencies. Rock was found at an average depth of one foot below the surface, but it was decided that the main distribution cables should be laid at shallow depth in the cover available. The majority of the three miles of cable provided was moledrained, but the more important sections of the main 500-pair cable were protected by steel pipe laid in trenches excavated by an Aveling Barford trench excavator. It was possible to utilise a joint trench with the electricity supply on one section of the route, but, in general, considerable care had to be taken to avoid interference with other services. Underground feeds to a number of the stands were necessary, and the newly introduced one-pair polythene cable was used for this purpose. Distribution to the majority of exhibitors was provided by drop-wiring from 36-ft. poles situated in a 1-ft. gangway between the rows of (back-to-back) stands. These pole routes were used jointly with the electrical authorities and the work of poling materially reduced. A number of steel poles were used for subsidiary distribution. It is a tribute to the care with which the construction was carried out that very few faults were experienced either on the external or internal plant during the show, despite appalling weather conditions. It was necessary, however, in one instance to erect a jointer's tent hurriedly over one section of the main cable route which became exposed due to abnormal traffic removing the top soil.

The "Royal Show" exchange opened on 26th June, 1950, and from the following call figures it will be seen that the apparent lavish provision of telephone plant was justified :—

	8 *a.m.*-8 *p.m.*	*Busy Hour*
Monday, 3rd July ..	22329	2322
Tuesday, 4th July ..	37527	4090
Wednesday, 5th July ..	39009	4265
Thursday, 6th July ..	36884	4494
Friday, 7th July ..	31872	4121
Saturday, 8th July ..	4649	1047

At the conclusion of the show, all plant was recovered and the showground returned to its normal condition. The exchange building and equipment were forwarded to Cambridge for the 1951 show, the underground cable and poles recovered, and the 32 kiosks transported bodily to their permanent sites in the Oxford countryside.

H. F. G.

RECOVERY OF LONDON-BRIGHTON NO. 3 AERIAL CABLE

The London-Brighton No. 3 cable erected by Post Office staff in 1931/32 was one of the first experimental long-distance aerial cables to provide 4-wire repeatered circuits when the introduction of "Trunk Demand" service was inaugurated. The cable was manufactured by Messrs. Johnson & Phillips and the Pirelli Cable Companies, who provided the London-Crawley and Crawley-Brighton sections, respectively, and consisted of 37 quads, the core of paper insulated 10 lb. conductors being laid in star-quad formation. This cable provided 37 4-wire repeatered telephone trunk circuits between London and Brighton, which had up to this time, been working on 70 lb. multiple twin cable without amplification.

Specially constructed loading coils having a D.C. resistance of 4·1 ohms and an inductance of 120 millihenries were installed at predetermined points and were fitted on poles at intervals of approximately 2,000 yards.

The cable was suspended on 7/14 steel strand wire throughout its entire length, except on spans exceeding the normal distance when "long span" construction was adopted. This arrangement consisted of the addition of an auxiliary strand attached to the poles at a suitable distance above the main strand attachments and clamped to the main strand in the centre of the span. An important feature in providing this auxiliary strand (7/12) was that the provision of additional poles to strengthen the route was avoided and also it reduced possible damage to the cable, caused by the swaying action of strong winds.

Although of an experimental nature, the cable has given good service in providing long-distance circuits over a considerable period of time, but with the provision of further underground trunk cables on this route, it was decided that the recovery of the Crawley-Brighton section should be effected and all working circuits transferred to other cables. This work was put in hand and recovery work was able to commence in March of last year. The work was allotted to several gangs placed at suitable intervals along the route, each gang being provided with motor transport, whilst one 30-cwt. stores-carrying vehicle was used to collect the recovered cable and place it in safe custody each night, a recently vacated small U.A.X. building on the route being used for this purpose. As the cable was taken down it was cut into lengths of 15 yards and coiled up to facilitate handling, each coil weighing approximately ½ cwt. At no time did a large amount accrue in local storage.

With nearly 18 miles of aerial cable to be recovered, representing some 54 tons of scrap, transportation to the Supplies Department was no small part of the operation, but with the co-operation of that Department's motor transport section and assistance by Area transport the arrangements were carried out in a smooth and efficient manner.

The recovery of this route will be greatly appreciated by those who desire to preserve rural beauty and the fine views seen from this famous road will be greatly enhanced.

E. H. B.

North Western Region

DOUGLAS (I.O.M.)—SKYREBURN CABLE

To improve the standard of service between the mainland and Isle of Man, a new submarine cable has been laid, the landing point on the Island being at Port Groudle, about four miles from Douglas.

Work on the island included the construction of a repeater station at Douglas, construction of a cable hut at Groudle, installation of about four miles of balanced pair cable between these places by Area staff and also the installation by Area staff of about 360 yards of submarine-type cable from the cable hut to a jointing point on the beach to link up with the submarine cable. All this work, including trenching and ductwork for the cables, was put in hand mid-1949 and completed early in 1950 in readiness for the laying of the submarine cable.

The laying of the submarine section of the cable was undertaken by H.M.T.S. *Iris*, and the ship arrived off Port Groudle on 22nd June, 1950, to proceed with the operations. A shore party, on landing, set up communication with the ship via a "walkie-talkie" and the ship's jointer opened up the land section of the submarine cable. This, on test, was found to be low insulation in the order of 25 megohms.

THE SHORE PARTY EQUIPPED WITH "WALKIE-TALKIE" SET.

The cable was, therefore, recapped and CO_2 left in under pressure for 12 hours. At the end of the period, pressure was maintained and an infinity reading obtained on retest. During the operation of applying gas, it was found that the gas did not pass through from one end of the cable to the other, due to a "stopper" incorporated in the cable at 200 metre intervals to prevent water running along the cable in the event of a fracture to the sheath. Gas was, therefore, applied at both ends.

"Sealing ends" of a special design, which at the hut end forms part of the termination and at the beach end half the submarine cable joint, were fitted to the cable. The insulation was satisfactory at the conclusion of these operations, but fell to approximately 300 megohms on the fitting of the lead cap at the beach end.

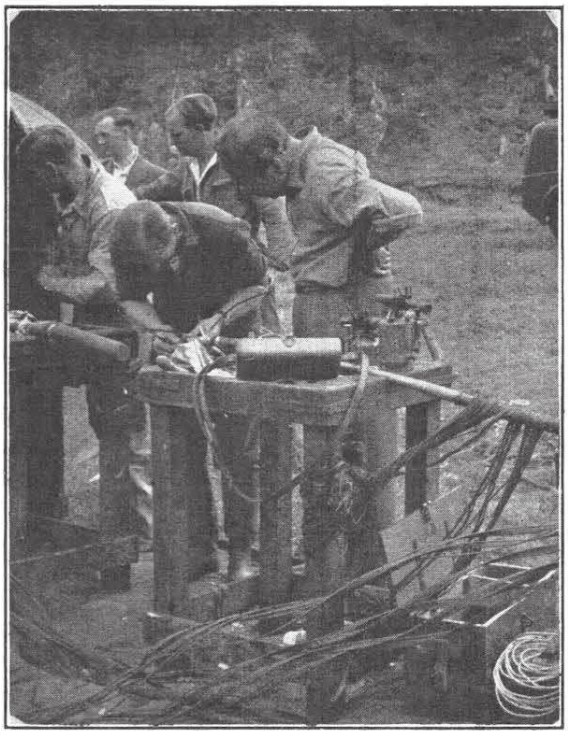
Several discussions took place and tests were then made to ascertain the reason for apparent instability of the cable. As a result, it appeared that, due to the large air space in the cable, damp air was too readily absorbed during the operation of fitting the air-tight sealing ends. These sealing ends were taking up to four hours to complete and with the temperature changes during this time it was considered feasible that the air would flow in and out of the air space in the cable, equalising with outside pressure. On cooling of the air within the cable, any moisture condenses on the Styroflex, causing a drop in insulation.

The beach end of the cable was eventually cut off and the cable reglanded at both ends. After the application of CO_2 gas for a period, the insulation was raised to over 1,000 megohms, to the satisfaction of the I Branch representative.

It was decided to land the sea end of the cable on 26th June, 1950, but weather conditions were unsuitable and the cable was eventually landed the following day. Satisfactory tests were made from the shore through the full length of cable in the ship's tanks, but the sea section of cable broke down, due to damage while the ship was swinging. A second shore end was landed which proved to be satisfactory.

The actual landing of the cable at Port Groudle was uneventful. A raft was built with two lifeboats from the ship, and sufficient cable to reach the agreed jointing point on the beach coiled on the platform. This raft was then towed from the ship, the personnel in the raft paying out the cable as shore was approached.

Completion of the laying of the sea section was delayed by unsatisfactory weather conditions, but was finally effected on 2nd July, 1950.



PREPARING FOR FINAL JOINTING OF LAND-SEA SECTIONS.

The 49·46 nauts of submarine cable is of the coaxial type, the centre conductor consisting of a steel wire approximately 0·184 in. diameter covered by a shell of copper to an overall diameter of 0·24 in. A laminated helix of Styroflex tap 0·135 in. wide is spiralled on to the centre conductor, and eight copper tapes forming the tube are bedded on to the Styroflex spiral. Two steel tapes are lapped over the outer conductor in opposite lay and covered with blue Styroflex ribbon over which is a lead sheath. The lead sheath is covered with tarred jute and armouring wire, giving an overall diameter of approximately 1·875 in.

B. W.

Junior Section Notes

Bishop's Stortford Centre

The membership suffered a disappointment in early September because a hoped-for trip to the De-Havilland Aircraft Factory did not materialise, due to pressure of work on the aircraft manufacturers. However, on 12th September an interesting film show was given by the Central Office of Information. The presentation included a film showing the various stages in the manufacture of both low- and high-tension cables.

On 18th October the first paper to be read since the inception of the Bishop's Stortford Centre was very ably given by Mr. R. Warboys. "Astronomy" was the subject of the paper, and the members present found it extremely interesting. This was followed on 8th November with a visit to the Observatory at Cambridge, where a very instructive and interesting evening was spent.

At the time of writing, the future programme included a paper on "Faraday Building Communications," by an E.-in-C.'s officer, to be followed later by a visit to Faraday Building, and a paper on "Internal Combustion Engines," by Mr. R. A. Collins.

Although in its infancy, interest in the Centre appears to be growing, but we would like to see still more join us. So come on in, those of you who have not yet done so. There is something of interest to everyone. J. S. R.

Darlington Centre

It is encouraging to any committee making programme arrangements to receive requests for the number of meetings to be increased. This is the happy position of the Darlington Centre, and the forthcoming programme is now as follows :—

16th January.—"Where the Money Goes," Mr. K. Millard.

20th February.—"Steel." Mr. W. French, A.M.I.M.E., C.E., F.I.W.M.

13th March.—"Two-Way Quiz." Darlington *v.* Middlesbrough.

10th April.—"Radar-Up-To-Date." Capt. R. R. Johnson, R.A.

15th May.—Annual General Meeting.

The Centre's activities commenced on 21st September, 1950, with a visit to the Darlington Power Station, which proved most interesting and educative. The talk by Mr. T. E. Daniels, of the North-Eastern Electricity Board, was exceptionally interesting.

The opening meeting of the session attracted a good number of our members, and the talk, "Audioddities," by Mr. H. C. Naylor, A.M.I.E.E., was thoroughly enjoyed. A lively discussion followed. Mr. Naylor has given several talks to the Centre in the past and his services are always appreciated.

The second meeting, "The Telephone Service in Hong Kong," by Mr. W. J. Geall, had to follow quickly after the previous meeting owing to Mr. Geall having to return to Hong Kong. The occasion was unique, because the speaker, formerly a member of the Darlington Post Office Engineering Staff, had returned after 25 years as District Manager of the Hong Kong Tele. Co.

A Darlington Junior Centre Member, Mr. G. Dale, journeyed to the York Centre and gave a talk, "U.A.X.s Simplified," on 12th October, 1950. This new departure in Regional Centre activities, proposed at the Area Conference, and implemented by Mr. A. C. Holmes, Regional Liaison Officer, is welcomed. G. N. H.

Tunbridge Wells Centre

The seventh winter Session commenced on 5th October, 1950, and the following officers were elected :—

Chairman : A. E. Chapman ; *Treasurer :* G. E. Kingswood ; *Secretary :* E. L. English ; *Committee :* Messrs. W. J. Edwards, A. G. Shoebridge, G. Harrison, J. Whyte, J. English, A. C. G. Hasted.

The programme for the 1950-51 Session will be continued as follows :—

January.—"Shared Service." E. L. English.

February.—"Fundamentals of Television." W. E. Thompson.

March.—"Some Further Aspects of Trunk Telecommunications in India." G. M. Blair.

April.—Film Show, followed by A.G.M.

Bradford Centre

The 1950-51 Session opened on 17th October with a visit to John Players, Ltd., Nottingham, when 31 members spent the afternoon touring the tobacco factory and left with a complimentary box of 25 "Players Please," The centre is indebted to the firm for a very interesting and instructive two hours.

A Quiz, Bradford *v.* Scarborough, took place on 3rd November over amplified land lines. The programme for the rest of the Session is given below :—

January.—"Ship-to-Shore Radio." Mr. E. Bauer.

February.—Hobbies Night. Exhibition Talk. Films. "O"-gauge Model Railway : ½-in. scale Steam Locos.

March.—"Transport in the Department." Mr. G. Lean.

April.—"Intercommunication Systems." Mr. J. Gleeson.

May.—Details later.

May.—Annual General Meeting.

Although a fairly full and comprehensive programme has been arranged, suggestions for its improvement will be welcomed from all members. A. E.

Glasgow and Scotland West Centre

Since the revival of the Centre it is pleasing to be able to record a continuation of enthusiasm by members, of whom there are 60, with every indication of a further increase.

The Committee has arranged a comprehensive programme, and the opening meeting took place on Friday, 29th September, when a very interesting evening was spent in the form of a Film Show and discussion. On Thursday, 19th October, 1950, members visited the works of Messrs. Scottish Cables, Renfrew, and on Friday, 17th November, 1950, Mr. J. Haddon, A.T.O., gave a lecture, illustrated with slides, his subject being "Some Aspects of Main Cable Maintenance."

The remainder of the programme is as follows :—

January	19th	"General Transmission"
February	16th	Visit to B.B.C.
March	16th	"Quiz"
April	20th	A.G.M.

May I draw members' attention to the excellent facilities offered by the Central Library of the Institution. For further information contact the Secretary, R. T. Shanks, PAI 2744.

The attendance at visits and lectures could be improved upon, and a special invitation is extended to youths-in-training. R. T. S.

(*Continued on page* 221)

Book Reviews

" The Theory and Design of Inductance Coils." V. G. Welsby, Ph.D., A.M.I.E.E. Macdonald & Co. (Publishers), Ltd. 180 pp. 61 ill. 18s.

Dr. Welsby uses an admirable mixture of theory and experiment to derive working formulæ for the design of many types of coil and the prediction of their resistances at high frequencies. The only serious criticism of this book is that this approach limits its scope more than the author may have realised; some of his statements that certain types of loss are unimportant, while true for the coils used in telecommunications systems, are not always true for the specialised coils needed for laboratory equipment (for which accurately-known performance may be even more important than for the bread-and-butter types). Similarly, his treatment for air-cored coils differs from that of Butterworth; the fundamental difference seems to be the author's assumption that, for good performance, the winding space will need to be nearly filled, while Butterworth assumed that the windings should be widely spaced. Both authors are right—they are thinking of different kinds of coil, for different purposes; unfortunately, neither of them gives a hint that the other kind of coil exists.

The debunking of Litz wire is welcome, and very simple—why did nobody think of it before?

The various chapters of the book are well proportioned, except that 17 pages on the technique of measurement are far too few. The reviewer disagrees with some of the author's recommendations on bridges, perhaps because they are not explained in enough detail.

The bibliography is useful as far as it goes; but it omits, for example, Butterworth's discussions of toroidal coils and of the resistance of closely-spaced turns, Howe's discussion of the principles of screening, and Rosa's papers on the inductance of spaced turns. Detailed references from the text to the bibliography would be helpful; at present, one must guess from the titles of the articles which of them is relevant to a particular problem. The contents pages and index are good. The diagrams are fair, but some of them are cramped and some do not show what the text says they do.

Generally, this book is excellent for the design of everyday coils for line communication work. For unusual coils it may help or it may not. It never avoids a difficult question if the answer is going to be needed in practice, yet everything in it is intelligible to the non-specialist.

A. C. L.

" Electrical Transmission of Power and Signals." Edward W. Kimbark. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 461 pp. 211 ill. 48s.

This is a general textbook covering basic theory appropriate to the transmission of power, telephony and ultra-high-frequency signals. As far as is known it is the first book to deal with the subject in this general way, and for the student who wishes to obtain a comprehensive knowledge of line transmission, it can be recommended without reserve. A knowledge of circuits with lumped parameters is assumed, but the book deals with distributed parameters from first principles. Rationalised m.k.s. units are used throughout.

Early chapters are devoted to the primary coefficients of two-conductor lines (coaxial and parallel wires), multi-conductor lines, stranded and miscellaneous conductors (dealt with from the conception of geometric mean distance) and ground-return lines. In using the formulæ given, the student will need to remember that R, L, G and C refer here to total quantities and not per unit of length. Elastance—the reciprocal of capacitance, in megadarafs per metre—will be an unfamiliar unit to most readers.

Steady-state transmission along uniform lines and the equivalent lumped networks are dealt with in a manner familiar to communication engineers, while transient phenomena are covered in a very practical manner in relation to switching surges, lightning and the transmission of D.C. pulses. Circle diagrams and other graphical methods of determining the performance of lines terminated in any impedance are derived, and the particular requirements of the power engineer follow.

The remaining six chapters apply mainly to the field of communication and first deal with impedance matching, image characteristics and signal distortion in a comprehensive manner; coil loading, superimposed circuits, crosstalk and line transpositions are also adequately covered. Coaxial cables are dealt with in the section on radio-frequency lines where such artifices as short-circuiting pistons and the many applications of quarter-wave-length stubs are conveniently included. There is a chapter on electric wave filters, but this confines itself to networks terminated in their image impedances, and makes only passing reference to dissipation. Skin effect is dealt with in some detail, first in flat plates and then in circular wires, the latter involving an introduction to the modified Bessel functions.

The final chapter discusses guided waves, the Poynting vector and the application of Maxwell's equations to wave propagation in rectangular and circular guides. Two appendices give useful and comprehensive data on practical conductors and transmission lines.

Each chapter contains an adequate list of references and many numerical problems for the exercise of the student.

R. J. H.

" Maintenance Manual of Electronic Control." Edited by Robert E. Miller. McGraw-Hill Pub. Co., Ltd., London, 1949. 304 pp. 200 ill. 39s.

This book has been written primarily for the electronic technician and its pages are full of detailed material and sound practical advice on installation as well as maintenance. The work was first published as a series of articles in an engineering magazine; each subject is dealt with by a specialist in a most authoritative and thorough manner.

The main subjects covered (following elementary circuit arrangements common to most electronic controls, general matters of installation and maintenance and testing equipment) are Timing Devices, Photo-Cells, Motor Control, Resistance-welding and Temperature Control, with a final chapter on Sealed Ignitron Rectifiers.

There is no doubt that novel results can be obtained in suitable circumstances from electronic control but progress in application is at present being hindered, for example, by lack of trained technicians and by fear of plant engineers arising from the apparently delicate nature of electronic equipment. That this fear is unfounded will be recognised by communication engineers who will not be discouraged by the length and complexity of the many " Trouble-Shooting Tables " (as they are called) given in this book. However, there is no doubt that to enable the best performance from electronic devices to be realised, even in ideal applications, the installation and maintenance staff must be specially trained. This book, therefore, to some extent fulfils a need, but it is seldom that any one maintenance man, or group, is required to cover the full scope of the work. Further, there are many diverse applications which perforce have been left undescribed, such as electronic plate-cutting machinery (using original drawings as templates) and component inspection, testing, etc., except in general terms.

J. P.

Staff Changes

Promotions

Name	Region	Date
Reg. Engr. to C.R.E.		
Hines, R. J.	N.E. Reg. to Scot.	1.11.50
Sen. Exec. Engr. to Reg. Engr.		
Summers, F.	E.-in-C.O. to Mid. Reg.	14.9.50
Area Engr. to Asst. Staff Engr.		
MacWhirter, R.	Scot. to E.-in-C.O.	1.11.50
Exec. Engr. to Sen. Exec. Engr.		
Urben, T. F. A.	E.-in-C.O.	30.10.50
Welsby, V. G.	E.-in-C.O.	8.11.50
Raby, R. E.	L.T. Reg.	18.8.50
Stonebanks, A. M.	E.-in-C.O. to L.T. Reg.	1.9.50
Mason, H. J. S.	E.-in-C.O.	1.10.50
Barratt, L. W.	S.W. Reg. to H.C. Reg.	4.10.50
Dixon, J.	N.W. Reg. to Scot.	1.11.50
Lafosse, L. P.	E.-in-C.O.	26.9.50
Marchant, P. A.	E.-in-C.O.	26.9.50
Exec. Engr. to Sen. Sc. Offr.		
Bassett, H. G.	E.-in-C.O.	16.10.50
Sc. Offr. to Sen. Sc. Offr.		
North, J. C.	E.-in-C.O.	9.11.50
Asst. Engr. to Exec. Engr.		
Polhill, C. T.	H.C. Reg. to E.-in-C.O.	2.9.50
Cox, E. B.	E.-in-C.O.	3.9.50
Wilson, A. A.	Scot.	7.9.50
Greenall, J.	N.W. Reg. to E.-in-C.O.	9.9.50
Came, C. H.	S.W. Reg.	3.8.50
Whitting, W. G.	S.W. Reg.	4.10.50
Burgess, C. L.	S.W. Reg.	3.8.50
Rolls, A.	Mid. Reg. to S.W.Reg.	19.8.50
Phillips, H. A.	S.W. Reg.	26.8.50

Name	Region	Date
Asst. Engr. to Exec. Engr.—continued.		
Reynolds, W. H.	E.-in-C.O.	22.9.50
Mainwaring, G.	Mid. Reg.	23.10.50
Seymour, P. W.	E.-in-C.O.	9.10.50
Kelly, P. T. F.	E.-in-C.O.	23.10.50
Rata, S.	L.T. Reg. to E.-in-C.O.	16.10.50
Collins, J. H.	E.-in-C.O.	25.9.50
Lowe, W. T.	E.-in-C.O.	16.10.50
Groves, K.	E.-in-C.O.	7.10.50
Judd, D. L.	E.-in-C.O.	16.10.50
Yeo, B. F.	E.-in-C.O.	25.9.50
Simpson, W. G.	E.-in-C.O.	25.9.50
Stoate, K. W.	E.-in-C.O.	25.9.50
Naulls, R. W.	E.-in-C.O.	10.10.50
Hawley, A. E.	E.-in-C.O.	16.10.50
Hawkins, A. P.	E.-in-C.O.	2.10.50
Williams, J. B. F.	E.-in-C.O.	9.10.50
McPherson, J. W.	E.-in-C.O.	19.9.50
Walker, R. R.	E.-in-C.O.	20.9.50
Thompson, C. D.	E.-in-C.O.	20.9.50
Shearme, J. N.	E.-in-C.O.	19.9.50
Jeynes, E.	E.-in-C.O.	19.9.50
Boggis, R. J.	E.-in-C.O.	25.9.50
McLusky, R. F.	E.-in-C.O.	25.9.50
Fudge, E. W.	E.-in-C.O.	2.10.50
Windell, S. R.	E.-in-C.O.	2.10.50
Stephenson, M.	L.T. Reg. to E.-in-C.O.	23.10.50
Spencer, H. J. C.	H.C. Reg. to E.-in-C.O.	13.11.50
Rawlinson, W. A.	E.-in-C.O.	13.11.50
Harding, D. J.	E.-in-C.O.	20.11.50
Tech. Offr. to Exec. Engr.		
Hare, A. G.	E.-in-C.O.	9.10.50
McGrath, H. T.	E.-in-C.O.	25.9.50
Tech. Offr. to Asst. Engr.		
Kitchen, F. T. W.	E.-in-C.O.	9.9.50
Evans, J. H. G.	E.-in-C.O.	12.10.50

Transfers

Name	Region	Date
Asst. Staff Engr.		
Couch, P. R.	E.-in-C.O. to N.E. Reg.	1.11.50
Sen. Exec. Engr.		
Chorley, J. W. A.	E.-in-C.O. to Civil Service Comm.	25.10.49
Exec. Engr.		
Padgham, F. V.	E.-in-C.O. to H.C. Reg.	1.10.50
Hudson, G. K.	E.-in-C.O. to N.Ire. Reg.	1.10.50
Thompson, J. E.	Mid. Reg. to N.E. Reg.	1.11.50

Name	Region	Date
Asst. Engr.		
Edwards, A. J.	E.-in-C.O. seconded to Anglo - Iranian Oil Company	2.10.50
Mallett, T. H.	E.-in-C.O. to Min. of Civil Aviation	9.10.50
Eason, D. J.	E.-in-C.O. to W.B.C. Reg.	16.10.50
Maxted, V. O.	W.B.C. Reg. to E.-in-C.O.	23.10.50
Farres, T. S.	L.T. Reg. to E.-in-C.O.	6.11.50

Retirements

Name	Region	Date
Exec. Engr.		
Smith, J. A.	Scot.	30.11.50
Asst. Engr.		
Masters, F. R.	L.T. Reg.	1.9.50
Dean, W. J.	Mid. Reg.	10.9.50
Gregory, E. G. S.	L.T. Reg.	10.11.50
Saville, E. W.	N.E. Reg.	18.11.50
Inspector.		
Basgallop, H.	L.T. Reg.	31.10.50

Name	Region	Date
Inspector—continued.		
Cooke, W. E.	E.-in-C.O.	9.11.50
Hindes, R. W.	L.T. Reg.	10.11.50
Aaron, R. H.	Mid. Reg.	23.11.50
Senior Draughtsman.		
Stewart, R. J.	Scot.	27.11.50
Leading Draughtsman.		
Wood, S. P.	L.T. Reg.	5.10.50
Lawrie, R.	Scot.	30.10.50

Resignations

Name	Region	Date
Exec. Engr.		
Tough, J. D.	S.W. Reg.	23.10.50
Scott, B.	E.-in-C.O.	6.9.50
Asst. Engr.		
Geercke, S. M. G.	E.-in-C.O.	31.8.50
Edgar, F. L.	E.-in-C.O.	10.10.50
Thomas, A.	E.-in-C.O.	31.10.50
Turner, W.	Mid. Reg.	30.11.50
Liddell, A.	Scot.	23.11.50

Deaths

Name	Region	Date
Asst. Engr.		
Fitzgerald, S. G. M.	L.T. Reg.	30.7.50
Jardine, S.	Scot.	3.10.50
Inspector.		
Bardsley, A.	N.W. Reg.	25.9.50
Weaight, A. T.	H.C. Reg.	15.11.50
Leading Draughtsman.		
Rooks, E. W.	H.C. Reg.	6.11.50

CLERICAL GRADES

Promotions

Name	Region	Date
Sen. Exec. Offr. to Staff Controller.		
Daly, G.	E.-in-C.O.	2.11.50
H.E.O. to Sen. Exec. Offr.		
Southgate, A. G.	E.-in-C.O.	1.10.50
E.O. to H.E.O.		
Root, J. M. (Miss)	E.-in-C.O.	1.10.50
C.O. to E.O.		
Milner, G.	E.-in-C.O.	5.8.50
Hicks, G.	E.-in-C.O.	13.9.50
Smart, C. H.	E.-in-C.O.	1.10.50

Transfers

Name	Region	Date
H.E.O.		
Quartermaine, H.	E.-in-C.O. to Ministry of National Insurance	7.11.50
E.O.		
Bevans, H. G.	E.-in-C.O. to Ministry of Labour	20.11.50

Retirements

Name	Region	Date
Staff Controller.		
Dunster, H. L.	E.-in-C.O. (Ill-health)	1.10.50
S.E.O.		
Baker, A. J.	E.-in-C.O.	30.9.50
H.C.O.		
Hamilton, D.	E.-in-C.O.	12.9.50

JUNIOR SECTION NOTES

(*Continued from page* 217)

Lincoln Centre

On Wednesday, 27th September, a limited number of members, together with invited representatives of the Senior Section, paid a most interesting visit to the telephone works of Messrs. Ericssons at Beeston, Notts.

On arrival the members were split up into four parties, and then conducted via different routes round a very representative number of departments of the works. The operations seen varied from the manufacture of the smallest screws and mountings, etc., to the assembly of complete suites of switchboards and bays of automatic equipment.

One process which attracted much attention was the R.F. heating of material used in the manufacture of moulded telephone cases. After a most enjoyable tour which ended with a tea in the canteen, the only regrets were that it was unavoidable that the time available for each department was so short.

D. C.

Middlesbrough Centre

The 1950-51 Session opened with a large attendance at a Film Display and Social Evening on 26th October. The Telephone Manager attended along with 41 members, 9 Senior members and 20 visitors. Thanks again to Mr. J. S. Gill, our Liaison Officer, for organising the social entertainment. It was agreed that an enjoyable evening had been spent by all.

At the time of writing these notes, we have a membership of 63 ; it is hoped that this figure will be increased as the Session develops. The officers for the 1950-51 Session are :—

Chairman : D. Paterson ; *Vice-Chairman :* C. Allison ; *Secretary :* J. Brown ; *Vice-Secretary :* R. R. Johnson ; *Treasurer :* K. Lynas ; *Local Committee :* Messrs. G. A. Buckle, W. Burke, J. Mansfield, P. B. Sawyer, H. D. Sloan, and E. E. Sparkes.

As usual an excellent programme was planned, and the remaining items are as follows :—

25th January.—"Television." B. V. Northall (Darlington Centre).

22nd February.—"Electrical Engineering in Iron and Steel Works." R. Dingwall, M.I.E.E.

13th March.—Two-Way Quiz : Darlington *v.* Middlesbrough.

10th May.—Annual General Meeting.

The Telephone Manager has generously offered £1 1s. as a prize for the best lecture given at Darlington or Middlesbrough Centre during the present Session.

J. B.

Southampton Centre

The Committee of the Centre has arranged a varied programme for the remainder of the 1950-51 Session to include the following :—

9th January.—A Quiz with Portsmouth Centre, using land-lines between the Centres.

13th February.—"Problems in Wartime Communications." H. Knee.

13th March.—"Telegraph Auto. Switching." R. Katon.

10th April.—Annual General Meeting, and "Five-Minute Papers out of the Hat."

In addition to the programme of papers, during the early months of 1951, arrangements are in hand for visits to the Terminal Building, Southampton Docks ; B.B.C. Transmitter, Bartley ; and Pirelli-General Cable Works, Eastleigh.

The Centre will also arrange further visits during the coming months if a sufficient number of members so desire.

N. H. R. Y.

BOARD OF EDITORS

H. Faulkner, C.M.G., B.Sc., M.I.E.E., Chairman.
F. E. Nancarrow, O.B.E., A.R.C.Sc., M.I.E.E.
A. H. Mumford, O.B.E., B.Sc.(Eng.), M.I.E.E.
W. T. Gemmell, A.C.G.I., B.Sc., M.I.Mech.E., A.M.I.E.E.
W. West, B.A., M.I.E.E.
D. A. Barron, M.Sc., A.M.I.E.E.
A. F. Stollard.
C. E. Moffatt, A.C.G.I., Wh. Ex., A.M.I.E.E.
G. E. Styles, A.M.I.E.E., Managing Editor.
W. A. Humphries, A.M.I.E.E.)
J. P. Harding, B.Sc.(Eng.), A.M.Inst.C.E., A.M.I.E.E.) Assistant Editors.
A. J. Hutchison, Secretary-Treasurer.

Copyright

The entire contents of this Journal are covered by general copyright, and special permission is necessary for reprinting long extracts, but Editors are welcome to use not more than one-third of any article, provided credit is given at the beginning or end thus : "From the *Post Office Electrical Engineers' Journal.*"

The Board of Editors is not responsible for the statements made or the opinions expressed in any of the articles in this Journal, unless such statement is made specifically by the Board.

Communications

All communications should be addressed to the Managing Editor, *P.O.E.E. Journal,* Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Telephone : HEAdquarters 1234. Remittances should be made payable to "*The P.O.E.E. Journal*" and should be crossed "& Co."

Binding Cases

Cases for binding are available, and may be obtained from the Local Agents for 2s. Subscribers can have their copies of volumes bound, at a cost of 7s. 6d., by sending the complete set of parts to the Local Agents or to the *P.O.E.E. Journal,* Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Orders for binding for Vols. 1-19 should indicate whether the original binding case with black lettering, or the later pattern with gold, is required. Cases with gold lettering are the only type stocked from Vol. 20 onwards.

Back Numbers

The price of the Journal, which is published quarterly, is 1s. 6d. (1s. 9d. post free) per copy, or 7s. per annum post free. Back numbers can be supplied, subject to availability of stocks, at 1s. 6d. each (1s. 9d. post free). Orders for back numbers may be sent to the Local Agents or to the Publishers.

Advertisements

All communications relating to space reservations should be addressed to the Advertisement Editor, *P.O.E.E. Journal,* Alder House, Aldersgate Street, London, E.C.1. Communications regarding advertisement copy, proofs, etc., should be addressed to the Publishers, Messrs. Birch & Whittington (Prop. Dorling & Co. [Epsom], Ltd.), 49 Upper High Street, Epsom, Surrey.

Post Office Electrical Engineers' Journal

Volume 43, April 1950—January 1951

INDEX

	PAGE NO.
A	
Alderson, J. H. A Method of Reducing the Vibration from Diesel Engine Generating Sets	43
Articulation Tests, A Reference Telephone System for	1
B	
Balcombe, F. G., and D. E. Watt-Carter. Burnham Radio Station	117
Bomford, K. D., and A. H. F. Hunt. A Survey of Modern Radio Valves (Part 4)	10
Book Reviews 7, 17, 22, 35, 48, 68, 84, 99, 124, 134, 141, 168, 176, 191, 197, 218	
Booth, Capt. C. F., and A. H. Mumford. Television Radio-Relay Links	23
Booth, Capt. C. F., A. H. Mumford and R. W. White. The London-Castleton Experimental Radio-Relay System	93
Boreholes, A Novel Method of Surveying	129
Bray, P. R. The Calculation of Phase Constant from Small Differences of Open and Closed Impedance	200
Bray, P. R. Testing Facilities in H.M.T.S. *Monarch*	36
Bray, W. J. A Survey of Modern Radio Valves (Part 6 (*a*))	148
(Part 6 (*b*))	187
Buoy Recovery, Improved Method of Cable	8
Burnham Radio Station	117
C	
Cable Buoy Recovery, Improved Method of	8
Cable in H.M.T.S. *Monarch*, The Electrical Power System for Handling	102
Calculation of Phase Constant from Small Differences of Open and Closed Impedance, The	200
Castleton Experimental Radio-Relay System, The London-	93
Centenary Meeting (*Oliver Heaviside*), 18th May, 1950, Notes on the	101
Chadburn, C. G., E. C. H. Seaman and D. A. Crow. The Use of a Piston Attenuator for Cable Testing in the Frequency Range 1-30 Mc/s	192
Chapman, R. H., and E. C. Shipley. A Drawing Office Aid in Isometric Projection	184
Commission Mixte Internationale (C.M.I.), Paris, 1950	205
Crow, D. A., E. C. H. Seaman and C. G. Chadburn. The Use of a Piston Attenuator for Cable Testing in the Frequency Range 1-30 Mc/s	192
D	
Desiccator Employing Silica Gel, A Trailer Motor	165
Design of Square-Law Rectifier Circuits for Measuring Instruments	74
de Wardt, R. H., and J. Swaffield. A Reference Telephone System for Articulation Tests	1
Dialling, National Trunk	169
Diesel Engine Generating Sets, A Method of Reducing the Vibration from	43
Distortion Measuring Set for Start-Stop Telegraph Signals, An Electronic	18
Dolan, W. H., and A. Morris. Local Line Plant: Pair Appropriation Records	69
Doors, Power-Operated	135
Drawing Office Aid in Isometric Projection, A	184
E	
Edinburgh Conversion from Non-Director to Director	142
Electrical Power System for Handling Cable in H.M.T.S. *Monarch*, The	102
Electronic Automatic Telephone Exchanges, Introduction to:	
Speech Path Switches and Line Signalling	61
Register Translators	177
Electronic Distortion Measuring Set for Start-Stop Telegraph Signals, An	18
F	
Flowers, T. H. Introduction to Electronic Automatic Telephone Exchanges:	
Speech Path Switches and Line Signalling	61
Register Translators	177
Frost, P. B. The Leakage of Direct Current and Potential Gradients in the Ground	125
G	
Generating Sets, A Method of Reducing the Vibration from Diesel Engine	43
Gibson, R. W. National Trunk Dialling	169
Gill, Sir Archibald's, I.E.E. Presidential Address	209
Gill, Sir Frank—Obituary	207
H	
Harris, D. J. Power-Operated Doors	135
Heaviside, Oliver:	
An Appreciation	100
Notes on the Centenary Meeting, 18th May, 1950	101
Helm, Capt. S. The Recovery of Two Timber Lattice Masts	16
Horton, G. P., D. C. Walker and D. L. Richards. Design of Square-Law Rectifier Circuits for Measuring Instruments	74
Hunt, A. H. F., and K. D. Bomford. A Survey of Modern Radio Valves (Part 4)	10
I	
I.E.E. Presidential Address, Sir Archibald Gill's	209
Implementation of the New Radio Frequency Allocation Table, The	202
Improved Method of Cable Buoy Recovery	8
Institution of Post Office Electrical Engineers 50, 107, 153, 210	
Introduction to Electronic Automatic Telephone Exchanges:	
Speech Path Switches and Line Signalling	61
Register-Translators	177
Isometric Projection, A Drawing Office Aid in	184
J	
Jones, C. E. Palmer. A Novel Method of Surveying Boreholes	129
Junior Section Notes 54, 112, 154, 217	
L	
Leakage of Direct Current and Potential Gradients in the Ground, The	125
Lee, Sir George. Oliver Heaviside—An Appreciation	100
Local Line Plant: Pair Appropriation Records	69
London-Castleton Experimental Radio-Relay System, The	93

M

PAGE NO.

Masts, The Recovery of Two Timber Lattice 16
McWalter, W. V. Edinburgh Conversion from Non-Director to Director 142
Method of Reducing the Vibration from Diesel Engine Generating Sets, A 43
Moffatt, J. J. A Trailer Motor Desiccator Employing Silica Gel 165
Monarch, Testing Facilities in H.M.T.S. 36
Monarch, The Electrical Power System for Handling Cable in H.M.T.S. 102
Morris, A., and W. H. Dolan. Local Line Plant: Pair Appropriation Records 69
Mumford, A. H., and Capt. C. F. Booth. Television Radio-Relay Links 23
Mumford, A. H., Capt. C. F. Booth and R. W. White. The London-Castleton Experimental Radio-Relay System 93

N

National Trunk Dialling 169
Notes and Comments 50, 106, 156, 208
Notes, Junior Section 54, 112, 154, 217
Notes, Regional 51, 108, 157, 212
Novel Method of Surveying Boreholes, A 129

O

Obituary—Sir Frank Gill 207

P

Palmer Jones, C. E. A Novel Method of Surveying Boreholes 129
Phase Constant, The Calculation of, from Small Differences of Open and Closed Impedance .. 200
Phase Measuring Circuit, A Simple 198
Piston Attenuator for Cable Testing in the Frequency Range 1-30 Mc/s, The use of a 192
Polarised Relay of Improved Performance, A .. 85
Potential Gradients in the Ground, The Leakage of Direct Current and 125
Power-Operated Doors 135

R

Radio Frequency Allocation Table, The Implementation of the New 202
Radio-Relay Links, Television 23
Radio-Relay System, The London-Castleton Experimental 93
Radley, W. G. Notes on the Centenary Meeting (*Oliver Heaviside*), 18th May, 1950 101
Recovery of Two Timber Lattice Masts, The 16
Rectifier Circuits for Measuring Instruments, Design of Square-Law 74
Reference Telephone System for Articulation Tests, A 1
Regional Notes 51, 108, 157, 212
Relay of Improved Performance, A Polarised .. 85
Richards, D. L., D. C. Walker and G. P. Horton. Design of Square-Law Rectifier Circuits for Measuring Instruments 74

S

PAGE NO.

Scott, B., and H. A. Turner. A Polarised Relay of Improved Performance 85
Seaman, E. C. H., D. A. Crow and C. G. Chadburn. The Use of a Piston Attenuator for Cable Testing in the Frequency Range 1-30 Mc/s 192
Seymour, R. A. A Simple Phase Measuring Circuit .. 198
Shipley, E. C., and R. H. Chapman. A Drawing Office Aid in Isometric Projection 184
Silica Gel, A Trailer Motor Desiccator Employing .. 165
Simple Phase Measuring Circuit, A 198
Staff Changes 57, 114, 162, 219
Survey of Modern Radio Valves, A:
Part 4.—Transmitting Valves for Use up to 30 Mc/s 10
Part 5.—Valves for Use in the Range 30-3,000 Mc/s (Bands 8 and 9) 78
Part 6 (*a*).—Valves for Use at Frequencies Above 3,000 Mc/s 148
Part 6 (*b*).—Valves for Use at Frequencies Above 3,000 Mc/s 187
Surveying Boreholes, A Novel Method of 129
Swaffield, J., and R. H. de Wardt. A Reference Telephone System for Articulation Tests .. 1

T

Telegraph Signals, An Electronic Distortion Measuring Set for Start-Stop 18
Television Radio-Relay Links 23
Testing Facilities in H.M.T.S. *Monarch* 36
Thomson, A. J. The Electrical Power System for Handling Cable in H.M.T.S. *Monarch* 102
Timber Lattice Masts, The Recovery of Two 16
Tissington, R. S., and L. K. Wheeler. An Electronic Distortion Measuring Set for Start-Stop Telegraph Signals 18
Trailer Motor Desiccator Employing Silica Gel, A .. 165
Turner, H. A., and B. Scott. A Polarised Relay of Improved Performance 85

U

Use of a Piston Attenuator for Cable Testing in the Frequency Range 1-30 Mc/s, The 192

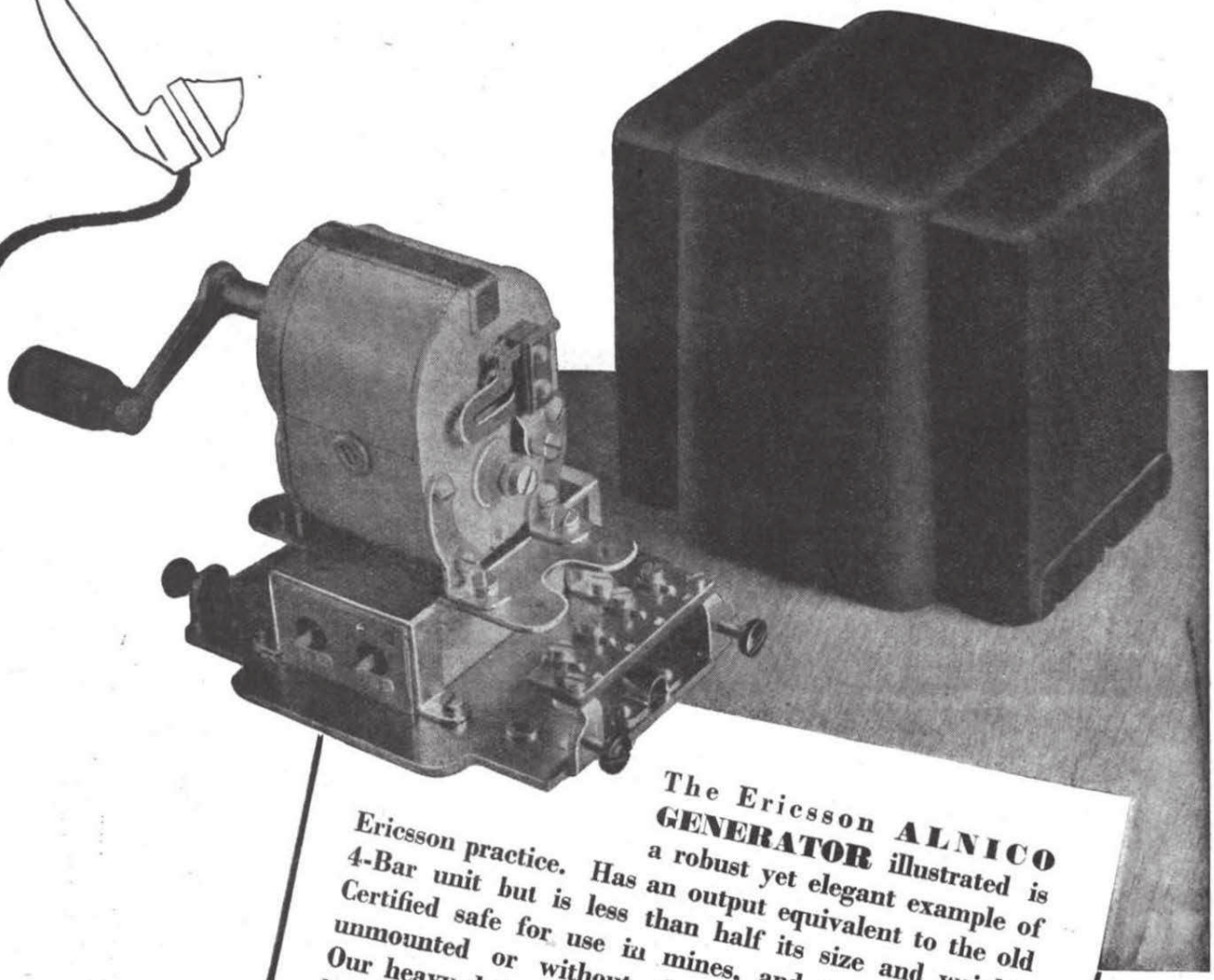
V

Valves, A Survey of Modern Radio .. 10, 78, 148, 187
Vibration from Diesel Engine Generating Sets, A Method of Reducing the 43

W

Walker, D. C., D. L. Richards and G. P. Horton. Design of Square-Law Rectifier Circuits for Measuring Instruments 74
Watt-Carter, D. E., and F. G. Balcombe. Burnham Radio Station 117
Wheeler, L. K., and R. S. Tissington. An Electronic Distortion Measuring Set for Start-Stop Telegraph Signals 18
White, R. W. A Survey of Modern Radio Valves (Part 5) 78
White, R. W., A. H. Mumford and Capt. C. F. Booth. The London-Castleton Experimental Radio-Relay System 93

MIGHTY midget . . .



The Ericsson **ALNICO GENERATOR** illustrated is a robust yet elegant example of Ericsson practice. Has an output equivalent to the old 4-Bar unit but is less than half its size and weight. Certified safe for use in mines, and can be supplied unmounted or without the moulded bakelite case. Our heavy duty **ALNICO** generator is slightly larger but uses the same case.

THE Ericsson ALNICO GENERATOR

ERICSSON TELEPHONES LTD. • *Head Office:* 22 LINCOLN'S INN FIELDS, LONDON, W.C.2. • *Tel:* HOL. 6936
Works: BEESTON, NOTTS.

R.F. ATTENUATOR
TYPE D-239

DELIVERY FROM STOCK

BRIEF SPECIFICATION

ATTENUATION RANGE : TYPE D-239-A : 0—61·5 db variable in steps of 0·5 db. TYPE D-239-B : 0—80 db variable in steps of 1 db. CHARACTERISTIC IMPEDANCE : 75 ohms (" T "-network). PERFORMANCE : At frequencies up to 5 Mc/s and for any setting of the switches the error in attenuation will not exceed ± 0·2 db. Reasonable accuracy is maintained up to 10 Mc/s. TERMINATIONS : Coaxial connectors. INPUT : 3 volts maximum. DIMENSIONS : 6½ in. × 2⅜ in. × 5¼ in. WEIGHT : 2½ lbs.
Manufactured to a design of the Radio Branch of the Post Office Engineering Department.

Full details are given in Bulletin B-562-B, a copy of which will be sent on request.

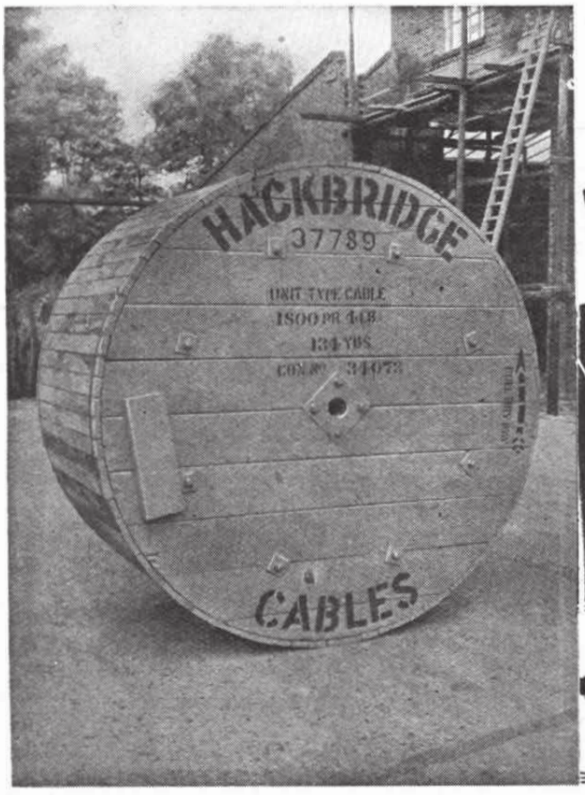
THIS small compact attenuator is characterized by a wide range of attenuation and outstanding accuracy at high frequencies. Wire wound resistance elements ensure accuracy, good stability and freedom from noise. It can be used as a bench instrument or for incorporation in other apparatus where its small size is a considerable asset. Two types, giving alternative values of total attenuation, are available.

MUIRHEAD

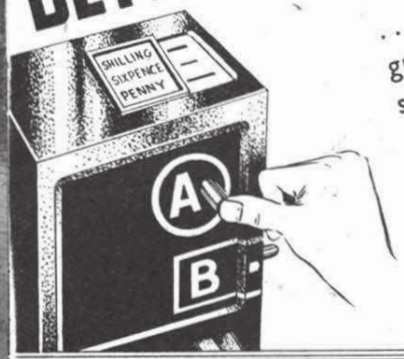
Muirhead & Co. Ltd., Elmers End, Beckenham, Kent. Telephone : Beckenham 0041-2.

FOR OVER 60 YEARS DESIGNERS AND MAKERS OF PRECISION INSTRUMENTS.

C.R.C. 636



BEYOND THE BUTTON....



.... Hackbridge underground dry-core air-space lead covered and armoured cable.

Contractors to G.P.O., British Railways, British and Colonial Government Departments.

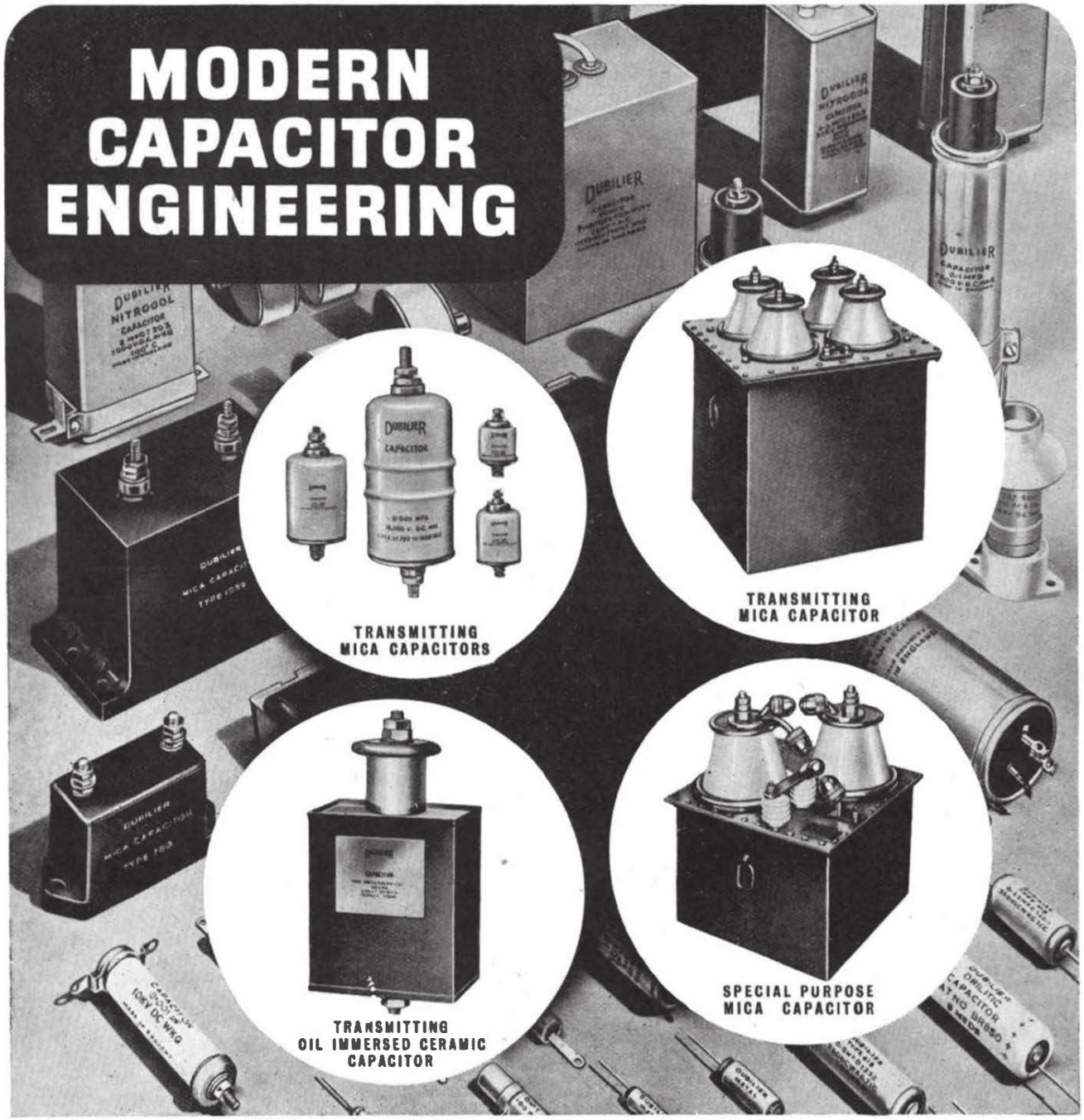
HACKBRIDGE *Cable Company limited*

KELVIN WORKS, HACKBRIDGE, SURREY

In Association with Bryce Electric Construction Company Ltd.

Branches at :

Birmingham, Bristol, Cardiff, Manchester, Newcastle, Sheffield



DUBILIER
CAPACITORS

Dubilier provide the most comprehensive range of Capacitors available today for Radio Transmitting and Receiving, in addition to Capacitors for Electronic and Industrial engineering.

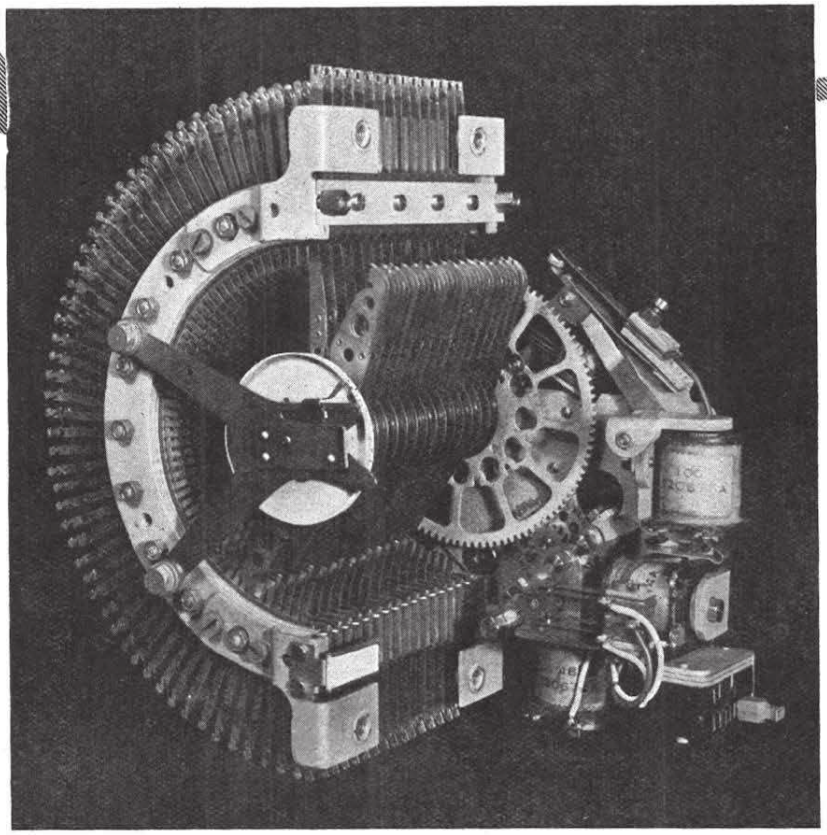
Dubilier Capacitors are designed and manufactured to a high standard of specification, suitability of purpose and meticulous capacitor engineering, and they satisfy the exacting demands of the British Postal Authorities whom we are proud to number amongst our customers. Full details and technical service upon request.

DUBILIER CONDENSER CO. (1925) LTD., DUCON WORKS, VICTORIA ROAD, N. ACTON, LONDON, W.3.

'Phone: Acorn 2241 (5 lines). Cables: Hivoltcon, London. Marconi International Code. 'Grams: Hivoltcon, Wesphone, London.

SIEMENS *High-Speed*

MOTOR UNISELECTOR

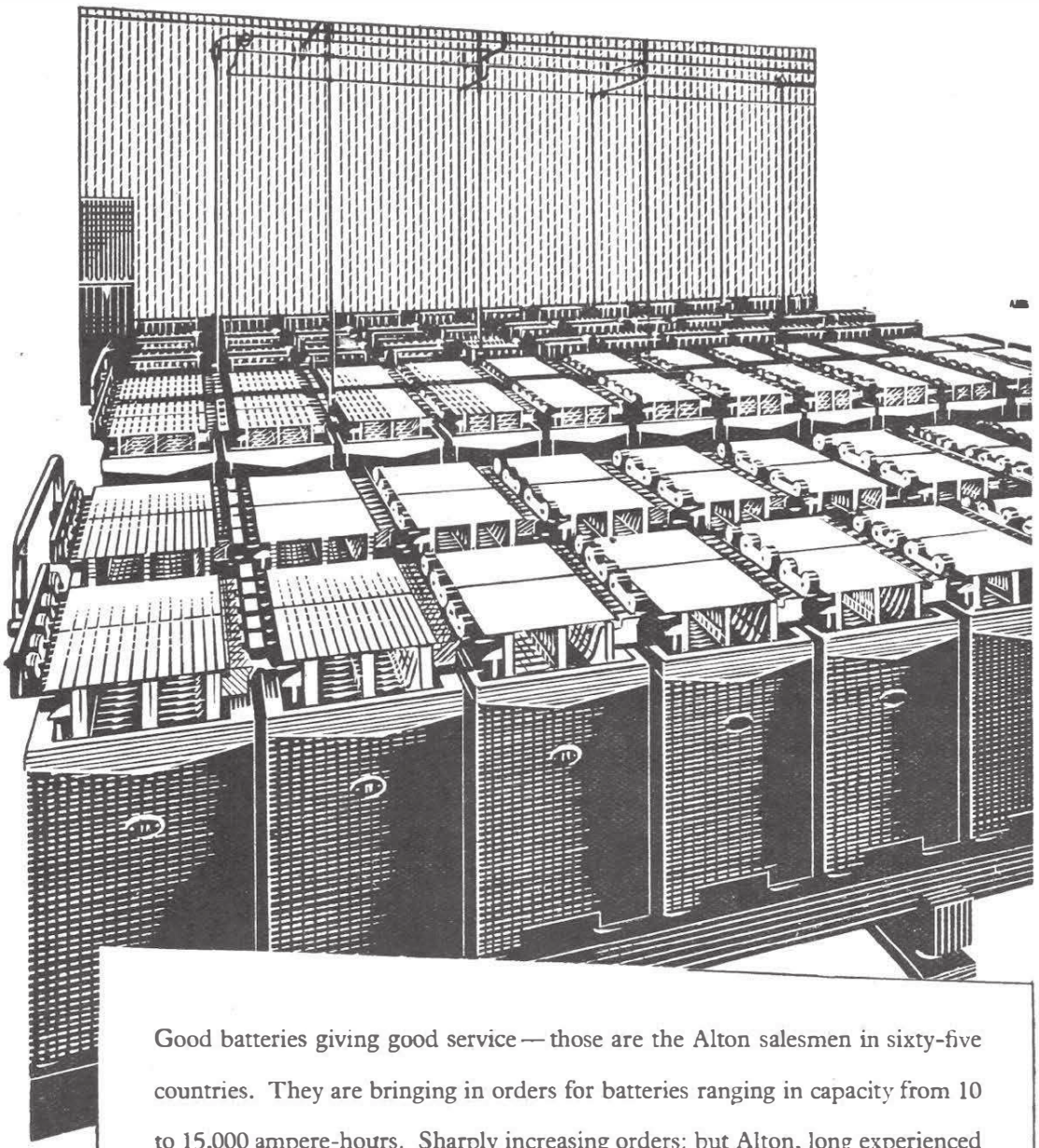


For their Trunk Mechanization Scheme the British Post Office has adopted the High-Speed Motor Uniselector illustrated above.

This Automatic switch has a searching speed of 200 outlets per second. This high speed together with its thorough reliability in operation render it the ideal switch for automatic trunk working.

The original type of Motor Uniselector has been in use for Line Finders at North Exchange, London, since June 1935

SIEMENS BROTHERS & CO., LIMITED
WOOLWICH · LONDON · S.E.18.



Good batteries giving good service — those are the Alton salesmen in sixty-five countries. They are bringing in orders for batteries ranging in capacity from 10 to 15,000 ampere-hours. Sharply increasing orders: but Alton, long experienced in export, is organised to meet them—with good batteries and firm delivery dates.

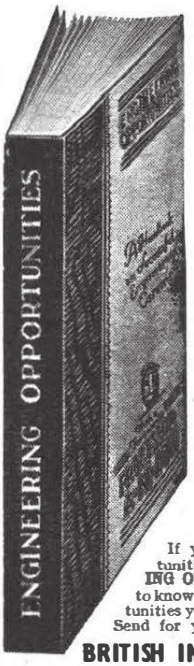
ALTON

Alton can also supply renewal plates for all makes of battery, British and Continental.

BATTERIES OF MERIT

THE ALTON BATTERY CO. LTD
Alton, Hants. Telephone: Alton 2267 and 2268. Grams: Battery, Alton

VALUABLE FREE BOOK



Tells You How to Pass Your C. & G. or Promotion Exam. at First Attempt!

All Post Office Engineering personnel who are anxious to obtain early promotion should at once send for a copy of our handbook **"ENGINEERING OPPORTUNITIES,"** which, among other intensely interesting matter, describes our unique methods of preparation for **TECHNICAL APPOINTMENTS IN THE POST OFFICE** (Assistant Engineer—New Style and Assistant Traffic Superintendent), **CITY AND GUILDS EXAMINATIONS** in Principles of Telecommunications (1-5), Radio (1-4), Telephone Exchange Systems (1-3), Telegraphy (1 and 2), Line Transmission (1 and 2), Lines Plant Practice (1 and 2), Mathematics for Telecommunications (1-5), Electrical Engineering Practice (Prelim. Inter. and Final), and outlines a wide range of non-examination courses in all branches of **Electrical, Mechanical, Civil, Automobile, Aeronautical and Radio Engineering.**

Assistant Engineer and Assistant Traffic Superintendent. Open competitions now resumed. Age extensions for established Civil Servants. Ask us for full details

We definitely guarantee "NO PASS—NO FEE"

If you intend to make the most of to-day's opportunities, you cannot afford to miss reading **"ENGINEERING OPPORTUNITIES."** It tells you everything you want to know to secure advancement, and describes many opportunities you may now be missing through lack of information. Send for your copy to-day—**FREE** and without obligation.

BRITISH INSTITUTE OF ENGINEERING TECHNOLOGY
369 SHAKESPEARE HOUSE, 17-19 STRATFORD PLACE, LONDON, W.1

BIET

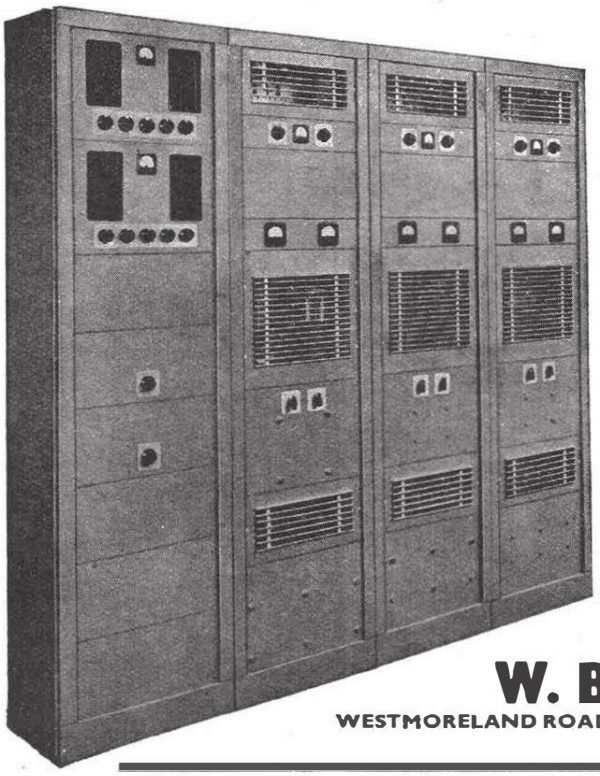
PITMAN'S
for Technical Books

TELEPHONY

By J. ATKINSON, A.M.I.E.E.
Area Engineer, Post Office Engineering Dept.

With the publication of Volume II, devoted mainly to the theory and practice of automatic switching, this great work is now complete. The new volume covers the latest advances in telecommunications practice, analyses the many problems of automatic telephony and examines the various recognized circuit elements. The two volumes together form an indispensable textbook and reference work for post office engineers and students. With over 1,500 illustrations. Vol. I (General Principles and Manual Exchange Systems) 35s. net. Vol. II, 50s. net.

PITMAN, *Parker Street, Kingsway, London, W.C.2*



The Mark II series of

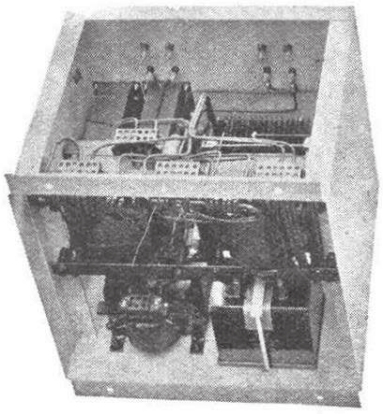
SAVAGE AMPLIFIERS
for Broadcast Relay

●These Amplifiers are examples of what careful design can achieve. A lift-off back panel affords immediate access for maintenance purposes and the removal of six screws releases the side covers of the rack and exposes all the interpanel wiring. Even when the rack is sandwiched between others the side covers can be moved just as easily. All valves are accessible from the front of the rack, and are protected by quick release grilles. The rack is completely flat fronted. The general appearance is further enhanced by the absence of a projecting front foot, and the masking of all panel fixing bolts. Similar racks carrying auxiliary apparatus can be placed side by side with amplifiers so that the whole installation is uniform in appearance.

Complete specifications available on request.

W. BRYAN SAVAGE LIMITED
WESTMORELAND ROAD · LONDON N.W.9 · TELEPHONE: COLINDALE 7131

CONSTANT POTENTIAL D.C.



A 250-watt WESTAT with cover removed.

For commercial and laboratory purposes where a source of power at a constant D.C. voltage is indispensable, equipments with outputs of up to 1,200 watts, or greater if required, are available in the "Westat" and "Noregg" systems of constant potential rectification. They are suitable for supplying a resistive or inductive load, and the "Westat" with the addition of a choke in the output can also be used in conjunction with a battery.

For details of these

WESTINGHOUSE WESTALITE METAL RECTIFIERS

write for Data Sheet No. 62 to Dept. P.O.1

WESTINGHOUSE BRAKE & SIGNAL CO. LTD., 82, York Way, King's Cross, London, N.1

DECADE RESISTANCES

in 3 Grades guaranteed

0·01% 0·03% 0·1%

SUPPLIED BOXED OR FOR CLIENT'S OWN PANEL

HIGHLY LAMINATED BRUSHES

LOWER DECADES OF ABSOLUTELY CONSTANT INDUCTANCE

EQUALLY SUITABLE FOR HIGH FREQUENCY LOW FREQUENCY OR DIRECT CURRENT

H. W. SULLIVAN

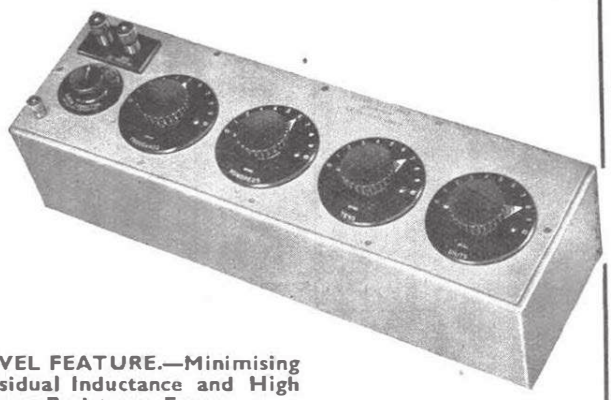
— LIMITED —

LONDON, S.E.15

Telephone : New Cross 3255 (P.B.X.)

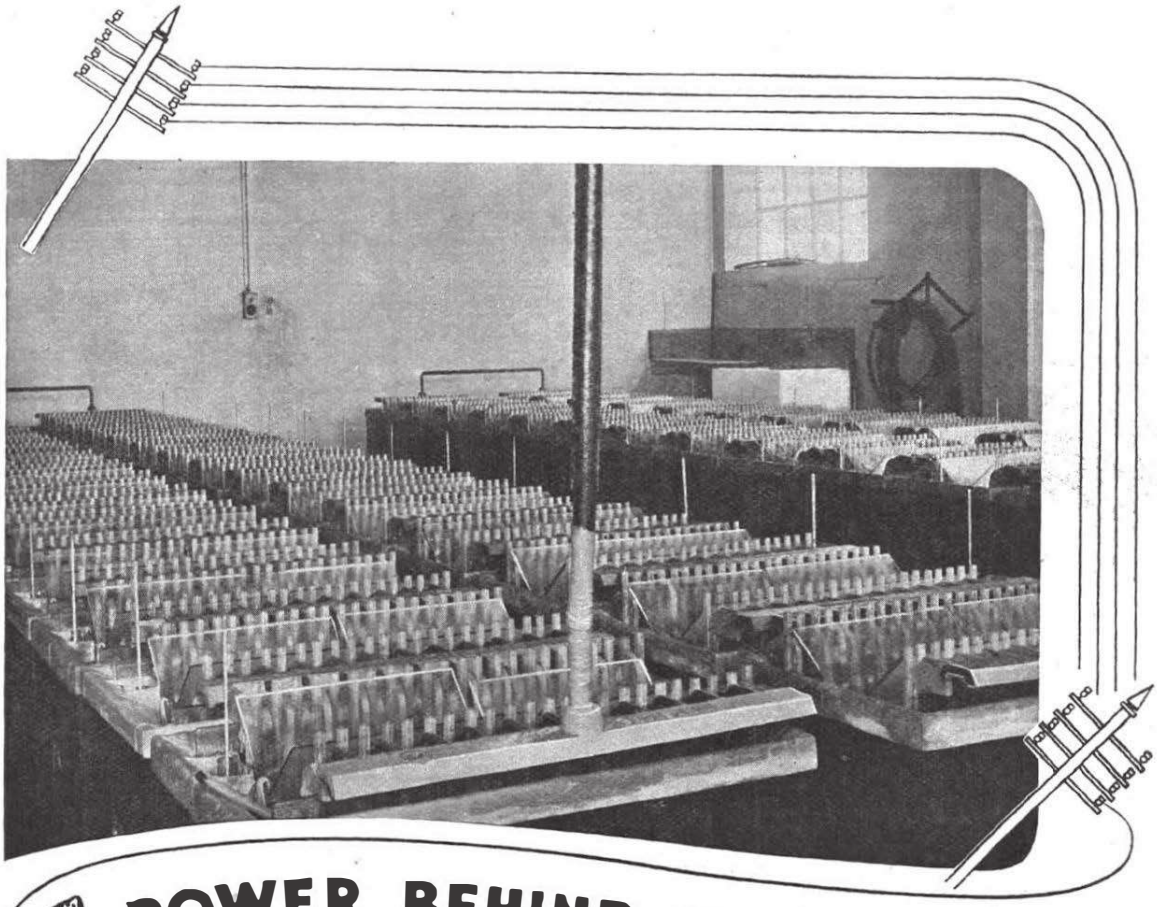
Electrical Standards for Research and Industry

Testing and Measuring Apparatus for Communication Engineering



A NOVEL FEATURE.—Minimising the Residual Inductance and High Frequency Resistance Error.

A patented method of reactance compensation is employed on the higher decades which compensates automatically for the screen capacitance and so renders the effective **residual inductance sensibly independent of the method of screen connection.** In addition, the user may, at will by the simple operation of a switch, adjust the reactance or resistance error sensibly to zero at the higher frequencies.



POWER BEHIND THE LINES

TUNGSTONE PLANTÉ CELLS are being supplied to the British Post Office and Post and Telegraph Departments in many countries overseas. They conform fully to G.P.O. and British Standard specifications.

OPEN TYPE CELLS

Similar to the illustration above, these are available in glass and/or lead lined wooden boxes in capacities from 100 a.h. to 500 a.h.

ENCLOSED TYPE CELLS

As illustrated on the right, these are in moulded glass boxes with sealed-in lids. Capacity range from 10 a.h. to 200 a.h.

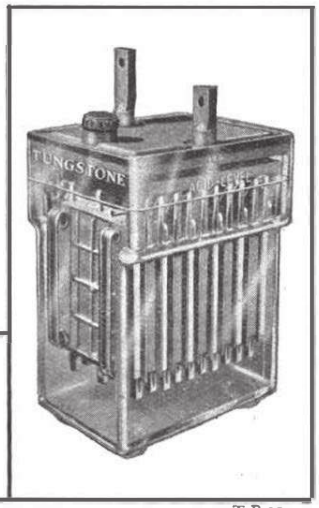
REPLATALS

We are in a position to supply plates for the replating of any existing Planté Battery.

HIGH VOLTAGE TELEPHONE BATTERIES

Portable Type. Standard layout for 50 volts, in waxed hard wood crates, exactly to the requirements of the G.P.O.

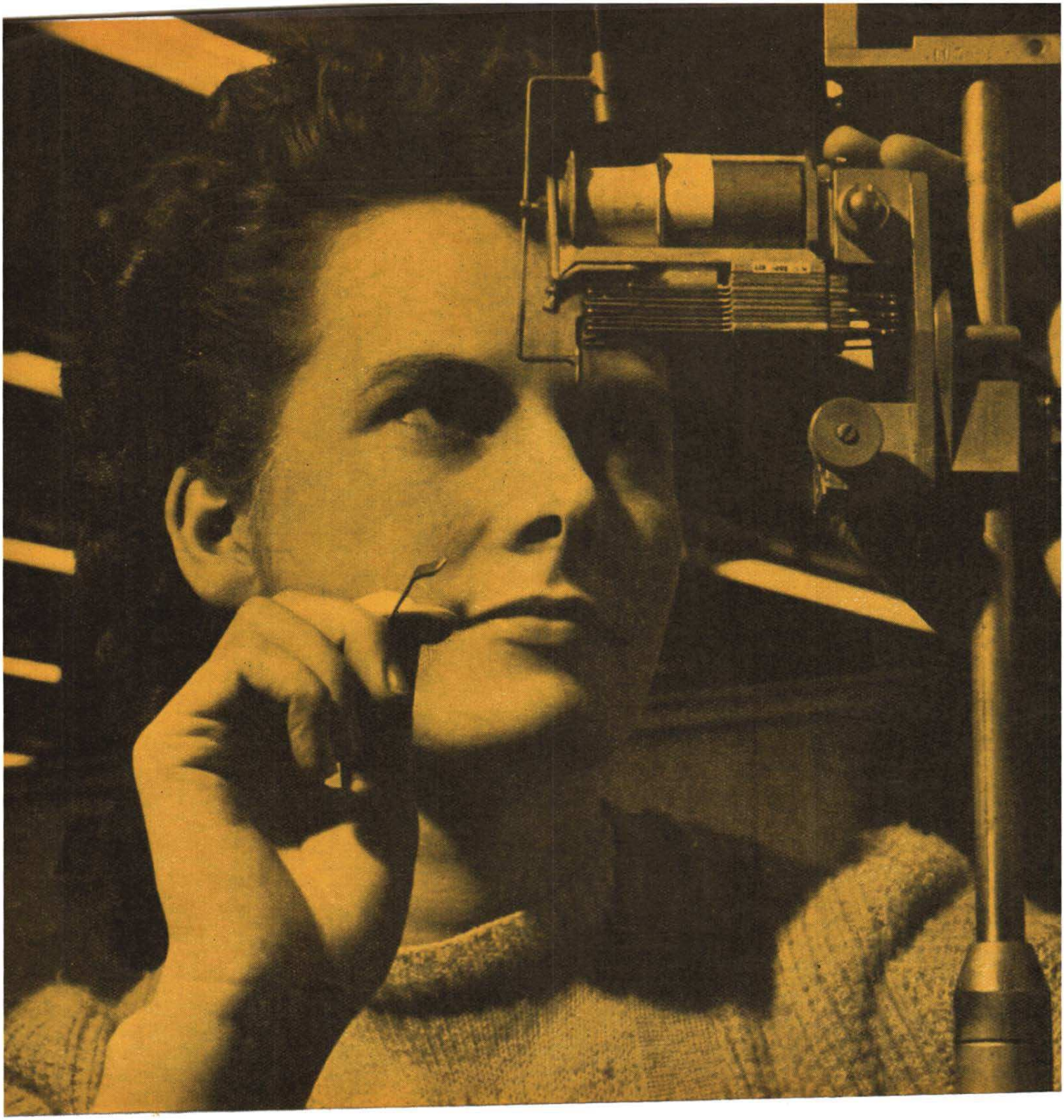
Overseas customers are invited to cable or write their enquiries for batteries or parts. Visitors to London are welcome at our offices.



TUNGSTONE *Batteries*

For further particulars write : **TUNGSTONE PRODUCTS LIMITED**
10 SALISBURY SQUARE · LONDON · E.C.4 · ENGLAND. Cables: "Dilutum" London.

T.B.12



PRODUCTS OF THE COMPANY INCLUDE: DIRECTOR AND NON-DIRECTOR AUTOMATIC TELEPHONE EXCHANGE EQUIPMENT, AUTOMATIC TRUNK EXCHANGES, RURAL AUTOMATIC EXCHANGES, PRIVATE AUTOMATIC EXCHANGES, PRIVATE AUTOMATIC BRANCH EXCHANGES, OPEN WIRE, CABLE AND RADIO TRANSMISSION EQUIPMENT; INTERCOM KEY-CONTROLLED TELEPHONE EQUIPMENT, CENTRALISED SUPERVISORY REMOTE INDICATION AND CONTROL EQUIPMENT; "RYTHMATIC" RIPPLE CONTROL EQUIPMENT; "ELECTRO-MATIC" VEHICLE-ACTUATED TRAFFIC SIGNALS; MINE TELEPHONES AND COLLIERY SIGNALLING EQUIPMENT.

AI263-A2·104

All relay springs are fitted with twin contacts to ensure faultless connection. This operator is adjusting contacts for correct alignment using an instrument specially designed for the purpose. All the operations involved in the assembly and testing of these mechanisms require a high degree of aptitude and skill.

From First Principles to Finished Product

In 1835 the first relay was invented by Joseph Henry as a natural product of his earlier researches into the principles of electromagnetism. This invention is, without doubt, one of the most important which has contributed to the development of the science of Telecommunications and there are today few communication systems which do not depend, either wholly or in part, on the operation of relays.

Constant research into the metallurgical, magnetic and electrical properties of relays is carried on in Strowger laboratories. The production departments manufacture scores of thousands of relays a week, this entire output being absorbed in the assembly of the Company's major products.

AUTOMATIC TELEPHONE & ELECTRIC CO. LTD.

Export Department: Strowger House, Arundel Street, London, W.C.2. Telephone: TEMple Bar 9262.

Cablegrams: Strowgerex, London. Strowger Works, Liverpool, England

P.O. Engineers rely on Bridge-Megger Testers

64% of all the faults on the 34,000 miles of main underground cables in the U.K. are located by Megger Testers.

Megger Testers play an important part in maintaining the efficiency of the Post Office communications system.

The 500 V. Bridge-Megger Tester is used by cable maintenance engineers for measuring the loop resistance and insulation resistance of underground cable pairs and for locating contact and dielectric faults of underground cable pairs. Dielectric faults with values ranging from full earths to several megohms, are successfully located depending upon the ratio of the " good " to " bad " wires. Varley, Murray, Simon and Poleck tests are carried out with the instrument.

Bridge-Megger Testers are widely used for routine maintenance tests, such as checking the insulation resistance of condensers or the value of suspected resistors.

Bridge-Megger Testers prove equally valuable to the Post Office down under. Instruments equipped with Varley fault localisation facilities are used extensively by the Australian Postmaster-General's Department for the location of faults on underground cables. They report that " it is outstanding when used to perform this function ".

The Bridge-Megger Testing Set is dual-purpose. In addition to being an insulation tester, it is capable of measuring to a high degree of accuracy a wide range of conductor resistances and is very suitable for fault location by the Varley Loop Method where the resistance of the loop is not less than one ohm.

Full details of its operation are contained in Publication No. X 212.

A Bridge-Megger Tester, Series 2, in use by the Post Office Engineering Department. The engineer is shown testing the insulation of 300 pair 6½ lb. P.C.U.T. cable at a pavement box.

Increased need to check Earth Systems regularly

The growing tendency of water companies to use asbestos-cement type water mains, resulting in several cases of electric shock recently in the Manchester and Rochdale areas, stresses the increased need for regular checking of electrical earthing systems.

The Megger Earth Tester enables the resistance to earth of an earth plate or structure to be measured directly in as simple a manner as possible. The Megger Earth Tester complies with the Testing requirements laid down in the I.E.E. Regulations, and is invaluable not only for the initial test of soil resistivity, but also to ensure by periodical tests that the low value of the soil resistivity is maintained.

Send for Publications Nos. X 051/20, 22 and 25.

EVERSHED

PROCESS CONTROLLERS · INDICATORS & RECORDERS
REMOTE CONTROLLERS · MEGGER TESTERS

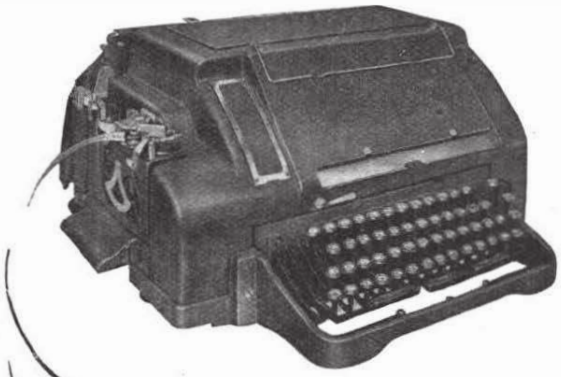
EVERSHED & VIGNOLES LIMITED

ACTON LANE WORKS · CHISWICK · LONDON · W.4

Telephone: Chiswick 3670 Telegrams: Megger, Chisk, London Cables: Megger, London

Creed
TELEPRINTERS

Built by specialists in machine telegraphy~

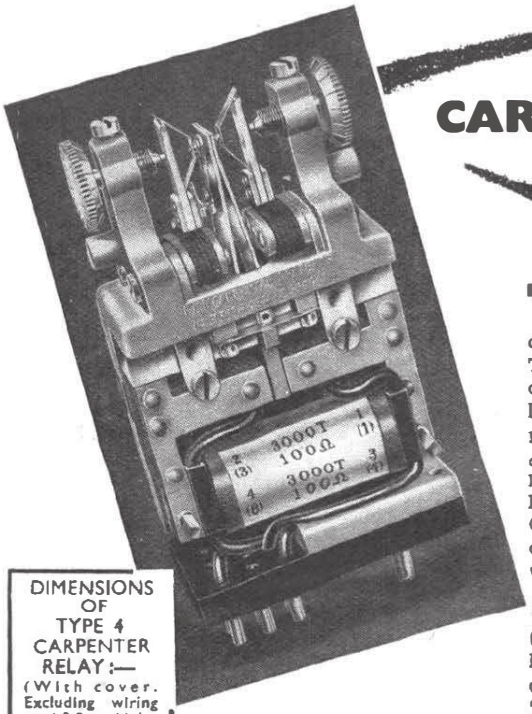


N°47 TAPE MODEL

Write for Bulletin N° 21

Creed & Company Limited

TELEGRAPH HOUSE
CROYDON, ENGLAND



DIMENSIONS OF TYPE 4 CARPENTER RELAY :—
(With cover. Excluding wiring tags) 3.5 ins. high x 2.2 ins. wide x 1 in. deep. Weight 13 ozs.

CARPENTER POLARIZED RELAY

TYPE 4

THIS is a medium speed, sensitive polarized relay designed primarily as a telephone impulsing relay (D.C. dialling up to 100 miles and V.F dialling on trunk circuits). It has also been successfully adopted for use in Telex systems, but can be used satisfactorily up to speeds of 100 c/s without contact chatter or serious bias disturbances.

Its sensitivity is such that when the gap is adjusted to .004 in. nominal, the relay will just operate at 50 cycles with 3.5 ampere-turns R.M.S. (corresponding to approximately 2 mVA) or on 4.5 D.C. ampere-turns at low speeds. In service, however, the relay is normally operated at currents substantially larger than the minimum operating current quoted.

Contact chatter is absent if the contact gap does not exceed .005 in. The contact gap is adjustable by means of fine pitch screws with knurled heads marked with .001 in. divisions. Contacts on the armature tongue are insulated from it and thereby from the frame.

The relay has a magnetic screening cover with transparent removable top to facilitate contact adjustment.

Dimensionally the relay is interchangeable with the type " 3000 " relay and can be supplied to fit directly to the drilling normally provided for the " 3000 " relay.

Termination can either be made by means of a 12 in. plug base as illustrated, or with soldering tags in place of the pins.

Developed & Manufactured by the Sole Licencees:— *Complete details available on request.*

TELEPHONE MANUFACTURING COMPANY LTD.

Contractors to the British Commonwealth and Foreign Governments

HOLLINGSWORTH WORKS • DULWICH • LONDON, S.E.21 *GIPsy Hill 2211 (10 lines)*

The AvoMeter is one of a useful range of "Avo" electrical testing instruments which are maintaining the "Avo" reputation for an unexcelled standard of accuracy and dependability — in fact, a standard by which other instruments are judged.

ONE INSTRUMENT

measures :—

Current, A.C. and D.C. (0 to 10 amps.)
Voltage, A.C. and D.C. (0 to 1,000 v.)
Resistance (up to 40 megohms)
Capacity (·01 to 20 mfds.)
Audio-frequency Power Output (0 to 2 watts)
Decibels (— 25 Db. to + 16 Db.)

Write for fully descriptive pamphlet.

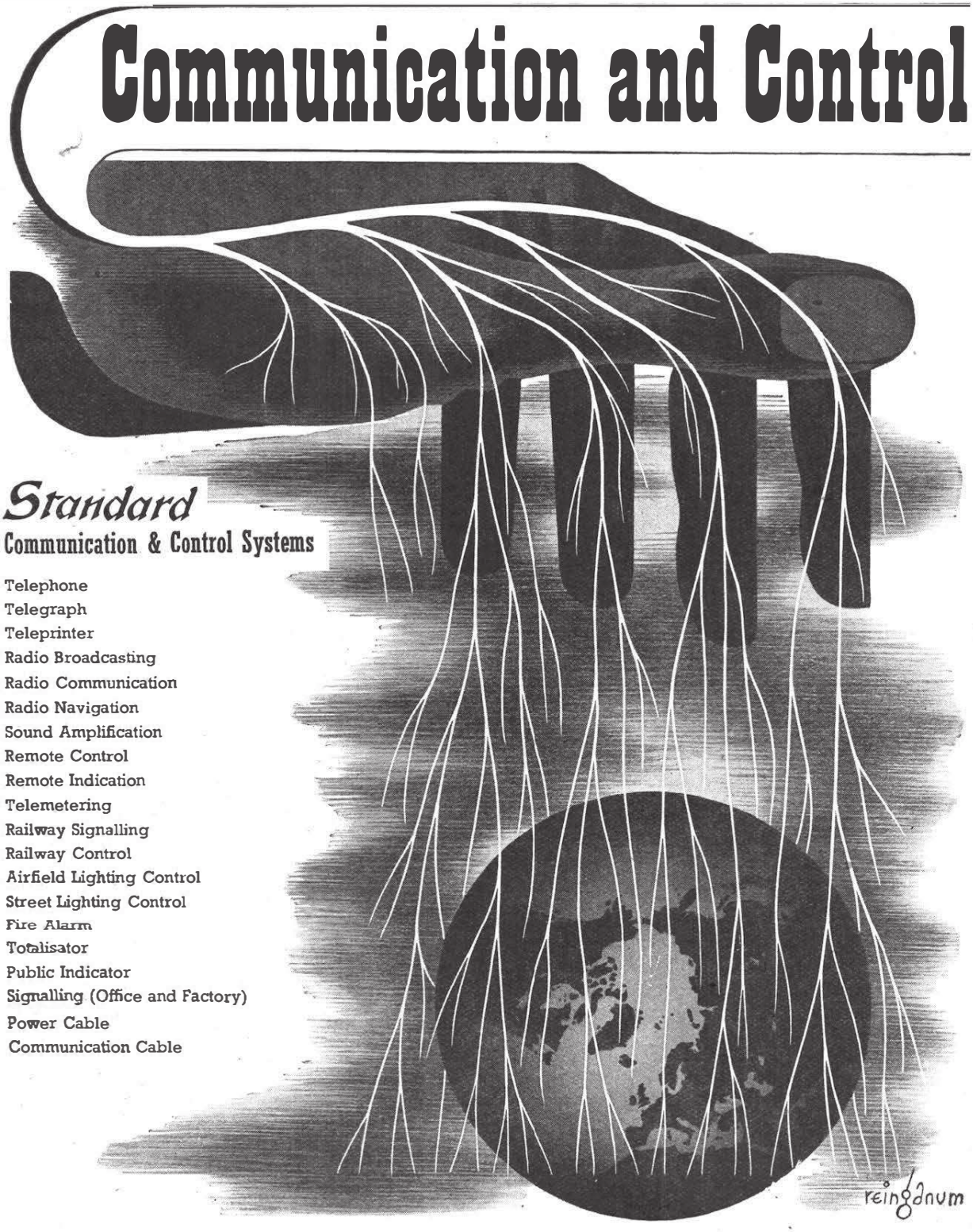
'AVO'

Meters that Matter

THE Model 7 Universal AvoMeter is the world's most widely used combination electrical measuring instrument. It provides 50 ranges of readings on a 5-inch hand-calibrated scale, and is guaranteed accurate to B.S. first grade limits on D.C. and A.C. from 25 c/s to 2 kc/s. It is self-contained, compact and portable, simple to operate and almost impossible to damage electrically. It is protected by an automatic cut-out against damage through severe overload.

Sole Proprietors and Manufacturers :—
THE AUTOMATIC COIL WINDER & ELECTRICAL EQUIPMENT Co. Ltd.
Winder House, Douglas Street, London, S.W.1. *Phone : VICtoria 3404-9*

Communication and Control



Standard
Communication & Control Systems

Telephone
Telegraph
Teleprinter
Radio Broadcasting
Radio Communication
Radio Navigation
Sound Amplification
Remote Control
Remote Indication
Telemetering
Railway Signalling
Railway Control
Airfield Lighting Control
Street Lighting Control
Fire Alarm
Totalisator
Public Indicator
Signalling (Office and Factory)
Power Cable
Communication Cable

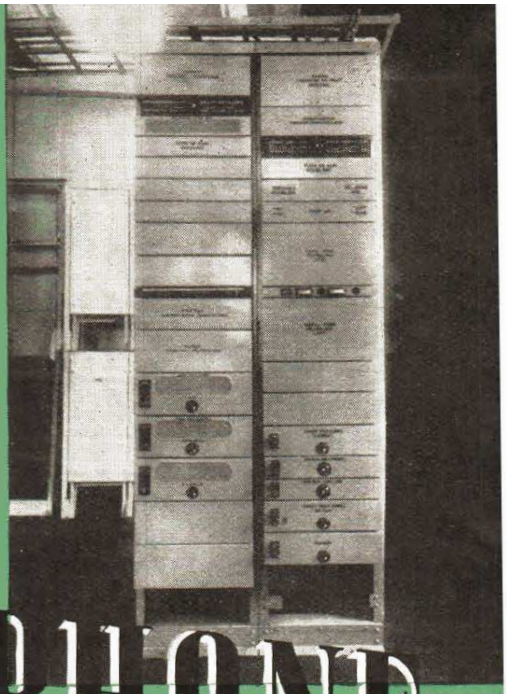
Standard Telephones and Cables Limited

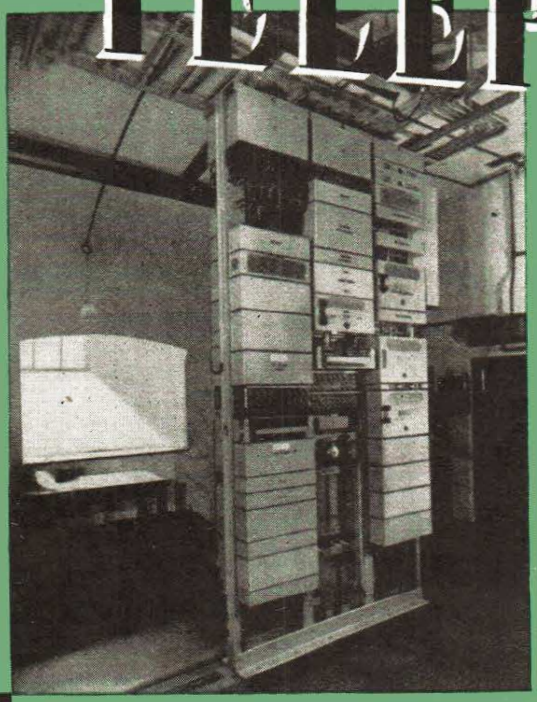
Telecommunication Engineers: Connaught House, 63 Aldwych, London, W.C.2

G.E.C.

TELEPHONE

Above—3-Circuit terminal bay.





Above — 12-Circuit open-wire equipment in the trunk telephone system of Turkey.

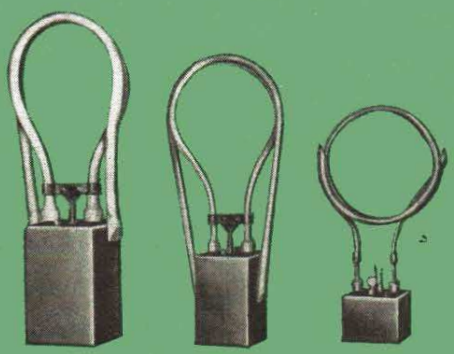
Left—Intermediate equipment at Howth (Eire) on the 24-circuit route linking Dublin to the trunk system of the U.K.

Lower left—Carrier and VF bays at Leeds for terminated and through circuits to 16 cities.

Cables and open-wire supplies by the associated company,

PIRELLI-GENERAL CABLE WORKS

SOUTHAMPTON



Loading coils, meters, and precision testing equipment by

SALFORD

ELECTRICAL INSTRUMENTS

LIMITED

SILK STREET, SALFORD

Proprietors:
The General Electric Co., Ltd.

MAJOR PRODUCTS IN THE LINE TRANSMISSION RANGE

Coaxial equipment for up to 960 circuits or a television link over coaxial cable.

Multi-circuit carrier equipment for underground cables, open-wire lines, and radio links.

Single- and three-circuit carrier equipment.

24-Channel VFT and 6-channel carrier-frequency telegraph equipment.

Picture-telegraph equipment.

VF repeaters for audio circuits.

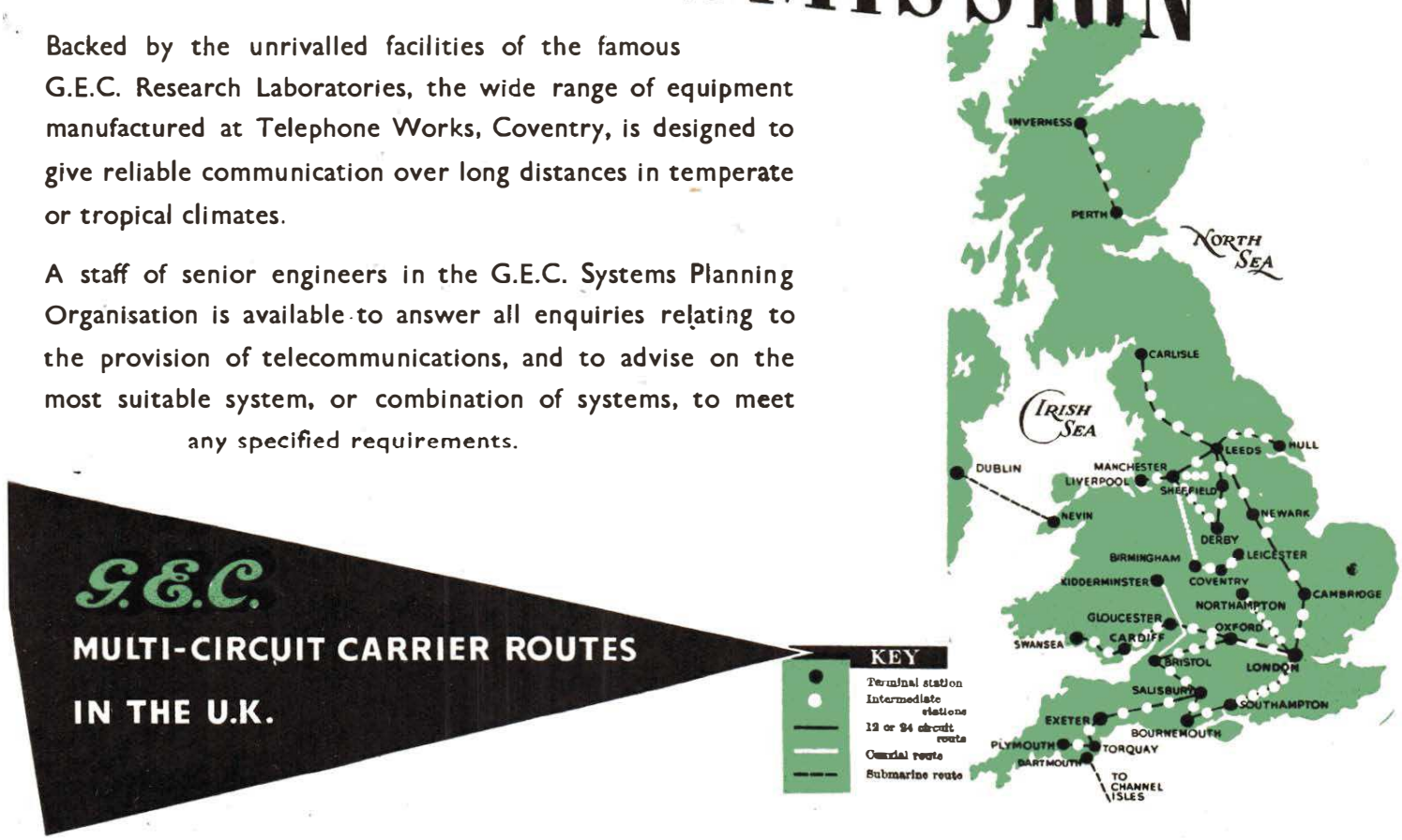
For association with line transmission equipment, multi-circuit two-way radio equipment has been designed for inclusion in trunk routes where erection and maintenance of lines would be less economic.

Coaxial system bays at Kidderminster.

LINE TRANSMISSION

Backed by the unrivalled facilities of the famous G.E.C. Research Laboratories, the wide range of equipment manufactured at Telephone Works, Coventry, is designed to give reliable communication over long distances in temperate or tropical climates.

A staff of senior engineers in the G.E.C. Systems Planning Organisation is available to answer all enquiries relating to the provision of telecommunications, and to advise on the most suitable system, or combination of systems, to meet any specified requirements.



THE GENERAL ELECTRIC COMPANY LTD. OF ENGLAND

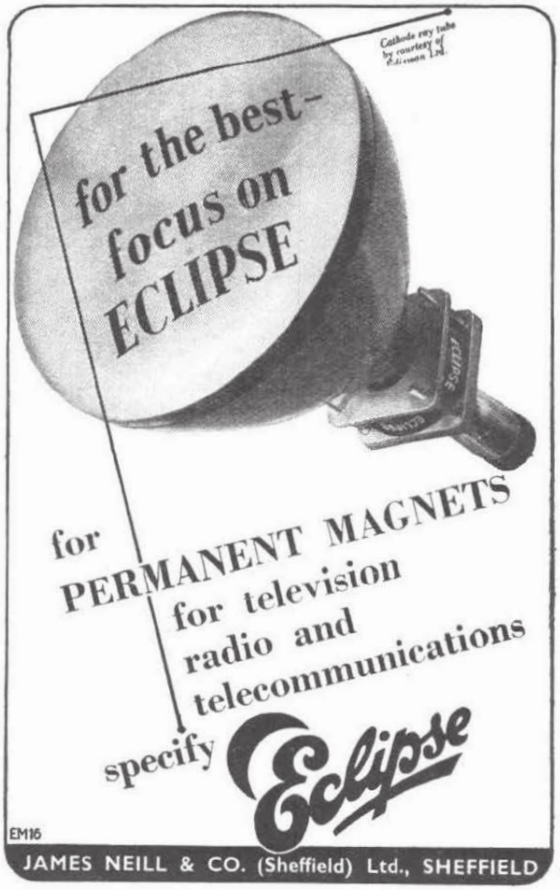
TELEPHONE, RADIO AND TELEVISION WORKS · COVENTRY · ENGLAND

HEADOFFICE · MAGNET HOUSE · KINGSWAY · LONDON · W.C.2.

The largest British electrical manufacturing organisation

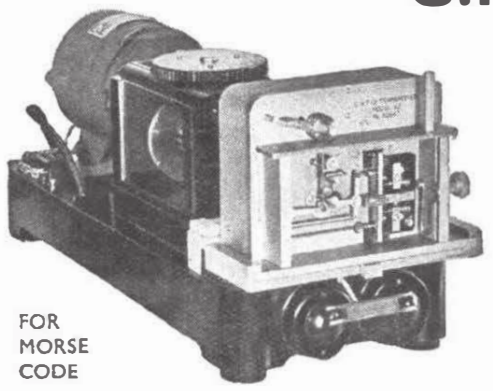
INDEX TO ADVERTISERS

	PAGE
Airmec Laboratories, Ltd.	xix
Alton Battery Co., Ltd., The	vi
Automatic Coil Winder & Electrical Equipment Co., Ltd.	xiv
Automatic Telephone & Electric Co., Ltd.	x, xi
Bennett College, The	ii
Berco	ii
British Institute of Engineering Technology	vii
Creed & Co., Ltd.	xiii
Dubilier Condenser Co. (1925) Ltd.	iv
Ericsson Telephones, Ltd.	iia
Evershed & Vignoles, Ltd.	xii
General Electric Co., Ltd., The	xvi, xvii
Great Northern Telegraph Co., Ltd.	xviii
Hackbridge Cable Co., Ltd.	iii
International Correspondence Schools, Ltd.	xix
Muirhead & Co., Ltd.	iii
Neill, James, & Co., Ltd.	xviii
Painton of Northampton	xx
Pirelli-General Cable Works, Ltd.	xx
Pitman, Sir Isaac, & Sons, Ltd.	vii
Savage Transformers	ii
Savage, W. Bryan, Ltd.	vii
Siemens Brothers & Co., Ltd.	v
Smith, Frederick & Co.	ii
Standard Telephones & Cables, Ltd.	xv
Sullivan, H. W., Ltd.	viii
Telephone Manufacturing Co., Ltd.	xvi
Tungstone Products, Ltd.	ix
Westinghouse Brake & Signal Co., Ltd.	viii
Winn & Coales, Ltd.	xix



UNIVERSALLY ADOPTED

G.N.T.Co. TRANSMITTER MODEL 112



FOR MORSE CODE

13-250 words per minute without gear changes or readjustments.

Absolutely constant speed at all settings notwithstanding large voltage variations.

Noted for its easy maintenance.

Supplied with A.C. or D.C. motors as required.

THE GREAT NORTHERN TELEGRAPH CO. LTD.

OF DENMARK

KONGENS NYTORV 28
COPENHAGEN K. - DENMARK

AND

5, ST. HELEN'S PLACE,
LONDON, E.C.3

Denso

provides all round protection

Denso Tape provides complete protection for pipes, mains, cables and all metalwork against the combined attacks of chemical and electrolytical corrosion. Permanently plastic—Denso forms a perfect gas- and water-tight seal that withstands the heaviest vibration. Ideal for emergency repairs —an aid to frost-proofing.

against CORROSION

Write for full details of Denso Anti-corrosive and Sealing Products without obligation, from :—

WINN & COALES LTD.
CHAPEL ROAD, LONDON, S.E.27
Telephone : GIPsy Hill 4247/8
Telegrams : Denselte, Westnor, London

SOUND INSTRUCTION by Postal Method

The I.C.S., largest school in the world devoted to spare-time training by the postal method, offers you highly specialised Courses for the following examinations :

P.M.G. Certificates for Wireless Operators.
C. & G. Illumination Engineering (Inter.)
C. & G. Electrical Engineering Practice, Installation and Telecommunications.
Graduateship of the B.I.R.E.

I.C.S. Examination students are coached till successful.

Other Courses meet the requirements of all who desire to qualify for responsible positions in Electric Power, Illumination, Heating and Traction Systems. Equally successful is our instruction for Telegraph and Radio Engineers, Radio Servicemen, and in Elementary Radar and Electronics, Advanced Short-Wave Radio and Television Technology.

Instruction is by correspondence from textbooks specially prepared by many experts.

WRITE FOR OUR SPECIAL BOOKLET and state the particular subject or Examination in which you are interested.

YOU MAY USE THIS COUPON

International Correspondence Schools Ltd.
Dept. 108, International Buildings, Kingsway, London, W.C.2

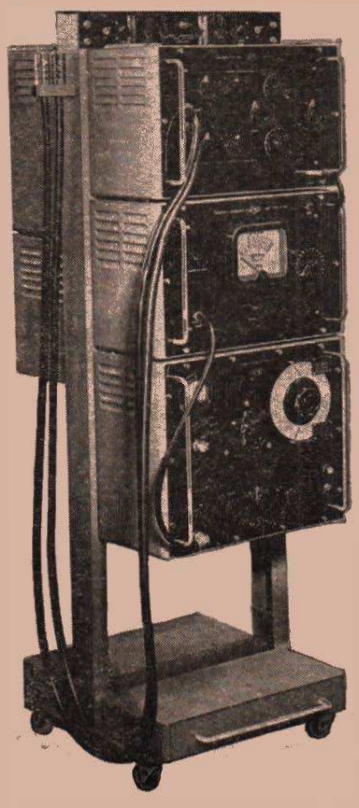
Please send me, free of charge, your special booklet on.....

Name..... Age.....
(Block Letters, Please)

Address.....

.....

ICS



AIRMEC

PHASE MEASURING EQUIPMENT

Type RX 103

This equipment, which is based upon a Post Office design, is primarily intended for the measurement of the phase-shift and gain of the $\mu\beta$ characteristics of feedback repeaters, over the frequency range of 50 kc/s to 20 Mc/s. It is also suitable for similar measurements on amplifiers, filters, equalisers and other four-terminal networks.

AIRMEC LABORATORIES LTD
HIGH WYCOMBE · BUCKINGHAMSHIRE · ENGLAND
TEL. HIGH WYCOMBE 3000 CABLES: AIRMEC HIGH WYCOMBE

A.L.(a) 4

TELEPHONE CABLES

OUR TELECOMMUNICATION CABLES CATALOGUE, GIVING INFORMATION AND SPECIFICATIONS FOR A WIDE RANGE OF TELECOMMUNICATION CABLES MANUFACTURED BY US, IS AVAILABLE UPON REQUEST.

TELEPHONE: SOUTHAMPTON 2141 (5 lines).

PIRELLI-GENERAL
CABLE WORKS, Ltd., SOUTHAMPTON.

TELEGRAMS "PIGEKAYBEL SOUTHAMPTON

In public address and music relay to various points requiring different levels, the most satisfactory method is to pre-set speaker output on stud faders, either at the control panel or on individual speakers.

Agent in Denmark :
Jonka Kondensatorfabriek A/S.
Holbergsgade 15, Copenhagen.

Printed by SANDERS PHILLIPS & CO., LTD., The Baynard Press, Chryssell Road, London, S.W.9, and Published by BIRCH & WHITTINGTON (*Prop. Dorling & Co. [Epsom], Ltd.*, Epsom, Surrey.